MORGAL-11-CIP

Date of Appeal Brief: September 30, 2008

In re application of: **Richard Morgal**

Serial No.: **10/821,593** Group Art Unit: **1795**

Filed: **April 9, 2004** Examiner: **Hall, Asha J.**

For: **METHOD AND APPARATUS FOR SOLAR ENERGY COLLECTION**

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William C. Boling 9-30-2008
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APPEAL BRIEF

Dear Sirs:

This Appeal Brief is submitted pursuant to a Notice of Panel Decision from Pre-Appeal Brief Review mailed May 30, 2008, and is accompanied by a petition for a three-month extension of time to respond together with a check for $780.00 for the corresponding small entity fees for the Brief ($255.00) and the Extension ($525.00). References are made to the application as filed April 4, 2004, and to the claims as currently pending.

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I. REAL PARTY IN INTEREST

The real party in interest is RICHARD MORGAL, the inventor, a resident of San Diego, CA.

II. RELATED APPEALS AND INTERFERENCES

On information and belief, there are no related appeals or interferences.

III. STATUS OF CLAIMS

Claims 1-14 are pending, and all stand rejected over Cluff in view of Laing.

Appeal is taken of the outstanding rejection of each of Claims 1-14.

IV. STATUS OF AMENDMENTS

An Amendment After Final Rejection mailed on February 27, 2008, canceling Claims 15-33, was entered by the Examiner. Claims 1-14 stand as amended in the Appellant's first Amendment, mailed August 30, 2007.

V. SUMMARY OF CLAIMED SUBJECT MATTER

The invention is a concentrating photovoltaic solar energy collection device, or a corresponding method, having one or more features suitable to enable two-axis tracking of concentrating photovoltaics with high cooling and/or areal efficiency.

It is known to dispose concentrating photovoltaic cells in pontoons that float in a liquid and thus may be turned relatively easily to align to the sun. Two-axis tracking using pontoons is known (Cluff), but has been rejected in favor of single-axis tracking by others (Laing) due to the difficulty of two-axis alignment and the need to separate pontoons to avoid shadowing adjacent pontoons. Shadowing a concentrating photovoltaic converter drastically impairs conversion efficiency. Concentrating photovoltaic cells must be cooled, and all prior art pontoon solar collectors provide such cooling by means of an expensive, cumbersome system subject to catastrophic failure.

The claimed invention describes two-axis tracking, pontoon-mounted photovoltaic energy collection with efficient and reliable cooling.

V.A Two-Axis Tracking Solar Collector Cooled By Exterior Thermal Contact

Apparatus Claim 1 and method Claim 8 each define a pontoon-mounted, concentrating photovoltaic solar energy collection apparatus (or method) that cools photovoltaic cells through thermal contact with an exterior of the support structure.

V.A.1 Claim 1

1. A **solar converter apparatus** (*e.g.*, paragraph 41, Fig. 1: collector 30) for converting incoming light to electricity, comprising:

a) **a support structure for floating on a liquid bath** (*e.g.*, paragraph 41, Fig. 1: pontoon body 26 floating on bath 22), the structure having:

i) **a substantially fixed relationship to an incoming light axis that is parallel to useful incoming light** (see ¶ 50, pg. 11 lines 3-7, also ¶ 43 describing Fig. 1, and Figs. 4-6 described in ¶ 59, 61-62 pg. 13 lines 12-17, pg. 13 line 29-pg. 14 line 14: incoming light rays indicated external to structure 26, having constant angle to structure as structure tilts to follow source),

ii) **an elevation rotation axis at a fixed azimuth alignment angle from the incoming light axis, the support structure being rotatable about the elevation rotation axis** (*e.g.*, paragraph 43 sentence three plus parenthetical note), and

iii) **guidance interface features** (*e.g.*,¶ 41 pg. 8 line 20, Fig. 1: spacing rods 32-33) connecting the support structure to a **guidance frame** (*e.g.*, ¶ 42 pg. 8 lines 23-28, Fig. 1: perimeter ring 36) that **aligns the elevation rotation axis at the fixed azimuth alignment angle to an azimuth of the source of incoming light** (¶ 42, ¶ 43 sentence 1, pg. 8 lines 23-31), and that provide a **rotation reference for the support structure rotation about the elevation rotation axis to align the incoming light axis with the source of incoming light** (¶ 41 sentence 4, pg. 8 lines 19-23: spacing rods 32-33 reference for control rods 34-45);

b) **at least one photovoltaic conversion device mounted within the support structure** (*e.g.*, target photovoltaic cells 100 in Figs. 4, 5 and 6) and adapted for converting concentrated sunlight into electricity; and

c) a **lens** (*e.g.*, roof lens 24 in Figs. 4-6, also pg. 15 line 1-pg. 19 line 11 *passim*, pg. 30 line 25-pg. 31 line 16) coupled to the support structure (26) for guiding light that is parallel to the incoming light axis and is received over a **receiving region** (region where light may be received, *i.e.*, the entire light receiving area of roof lens 24, Figs. 1, 4-6, see ¶ 61, pg. 14 lines 1-4, and Claim 5) toward a conversion device (100) that is mounted within the support structure (26), the conversion device having an **active area that is smaller than an area of the receiving region** (*i.e.*, the light should typically be concentrated by the area ratio, see ¶ 61, pg. 14 lines 1-4);

wherein the liquid bath (22) is a coolant that provides primary cooling of the conversion device (100) **through thermal contact with an exterior** (¶ 63, pg. 14 lines 17-21; ¶ 65 pg. 15 lines 1-8; pg. 7 lines 12-19) of the support structure (26).

V.A.2 Claim 8

8. A method of collecting incoming light for conversion to electricity, comprising:

a) mounting a **conversion device** (target photovoltaic cells 100 in Figs. 4, 5 and 6, *e.g.*, pg. 13 lines 12-17, 22; a primary focus of the description, *passim*; also pg. 28 line 14 - pg. 30 line 2) at a **mounting site** (*e.g.*, 96 in Figs. 4, 6, ¶ 63, pg. 14 lines 17-27) within a **support structure** (*e.g.*, pg. 8 lines 16-18, ¶ 41, Fig. 1: pontoon body 26, *passim*) having an **elevation rotation axis** (*e.g.*, pg. 11 lines 3-7;¶ 43, pg. 9 lines 2-6; ¶ 41 pg. 8 lines 19-22; 230 in Fig. 12, ¶ 79 pg. 19 lines 17-19);

b) coupling a **lens** (¶ 33 pg. 6 lines 16-24; roof lens 24 in Figs. 4-6, pg. 13 line 12-pg. 14 line 16, also pg. 15 line 1-pg. 19 line 11 *passim*, pg. 30 line 25-pg. 31 line 16) to the support structure (26) to **concentrate** (¶ 33, pg. 6 lines 16-24) and **guide incident light arriving parallel to an incoming light axis** (*e.g.*, ¶ 50 pg. 11 lines 3-7) toward the conversion device (100);

c) **floating the support structure on a liquid bath** (bath 22 in Figs. 1, 4-6, pg. 8 line 16);

d) **aligning the support structure so that the elevation rotation axis is at an azimuth alignment angle with respect to a source of light energy** (¶ 31 pg. 6 lines 4-7; ¶ 38 pg. 7 line 30 - pg. 8 line 1; ¶ 43 pg. 8 line 29 - pg. 9 line 6);

e) **rotating the support structure about the elevation rotation axis to align the incoming light axis toward the source of light energy** (*e.g.*, ¶ 31 pg. 6 lines 7-8; ¶ 38 pg. 8 lines 1-5;¶ 50, pg. 11 lines 3-7; pg. 10 line 17 - pg. 13 line 10 *passim*); and

(f) **cooling the conversion device primarily through thermal contact between the liquid bath and an exterior of the support structure** (¶ 65 pg. 15 lines 1-8; pg. 7 lines 12-19; ¶ 63, pg. 14 lines 17-21).

VI. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

The following issues are presented for review:

Whether Claims 1-4, 7-10 and 13-14 are unpatentable under 35 USC 103(a) as obvious over Cluff (US 4,771,764) in view of Laing (US 5,445,177).

Whether Claims 5-6 and 11-12 are unpatentable under 35 USC 103(a) as obvious over Cluff in view of Laing and further in view of Genequand (US 4,238,246).

VII. ARGUMENT

VII.A. SUMMARY OF MOST SIGNIFICANT EXAMINATION ISSUES

VII.A.1 Introduction to the Prior Art and the Problems

Cluff introduced pontoon solar collection, teaching that the pontoons should be rotated in two axes (two-axis tracking) so as to always point the collection surface directly at the sun. Cluff teaches cooling photovoltaic cells only by means of forcing coolant through a tube that runs near the cells.

Laing concluded that the system taught by Cluff was impractical, either because adjacent pontoons shadowed each other and thus destroyed conversion efficiency, or else the pontoons had to be widely separated and therefore the "areal efficiency," efficient use of available area, was very poor. Moreover, precise alignment to the sun in two axes is always difficult.

To avoid the problems he found with Cluff, Laing turned to a completely different principle of operation: single-axis tracking, in which the pontoons do not point their collection area at the sun. In single-axis tracking, the pontoons are not rotated about their longitudinal axis. Instead, the pontoons are able to remain stationary with respect to each other, and are aligned only as a group. Each pontoon is aligned parallel to the azimuth of the sun, whereas for two-axis tracking, pontoons must be aligned perpendicular to the azimuth of the sun, so that the pontoon can be rotated about its longitudinal axis to track the elevation of the sun. Single-axis tracking pontoons are aligned only to the azimuth of the sun.

Single-axis tracking pontoon arrays move only as a group, and remain stationary with respect to each other. Consequently, pontoons may be disposed immediately adjacent to each other without shadowing each other. With pontoons immediately adjacent, the "aperture," or area over which sunlight is accepted by the collectors, includes most of the space provided for the pontoons. Areal efficiency is very much higher than with the system taught by Cluff, while still avoiding the disastrous impairment of efficiency caused by shadowing.

Laing avoided the problems of Cluff by completely changing Cluff's two-axis tracking principle of operation. But while Laing's technique for aligning the sun to photovoltaic converter cells was drastically different, his technique for cooling the photovoltaic cells was essentially

unchanged from that taught by Cluff: forcing coolant through one or more tubes running near the photovoltaic cells. Moreover, Laing was never able to design a single-axis tracking system that focused the sunlight on the photovoltaic converters anywhere nearly as effectively as could be accomplished with two-axis tracking.

VII.A.2 Introduction to the Inventor's Solutions to the Problems

The Inventor was intimately familiar with the difficulties faced by Laing, and concluded that the problems caused by single-axis tracking could not be overcome economically. He therefore rejected Laing's single-axis tracking solution to the problems of Cluff, and resolved to find other means to overcome the acknowledged problems of Cluff.

The independent claims, as currently pending, are based on the Appellant's improvements to cooling of the concentrating photovoltaic cells. First he designed the pontoons so that the photovoltaic cells had excellent thermal conductivity to a part of the exterior of the pontoon. The second part of the problem was getting adequate thermal connection between that part of the exterior of the pontoon and the coolant liquid in which the pontoon was floating. This problem was greatly exacerbated by the requirement for two-axis tracking pontoons to rotate about their longitudinal axis over a wide angle, which was necessitated by his rejection of Laing's single-axis tracking approach. The pontoons tend to float quite high in their liquid bath, and the part of the exterior near which the photovoltaic cell was mounted would rise out of the liquid bath at some working angle of the pontoon, rendering the cooling inadequate to protect the photovoltaic cells.

The subject application proves that the inventor finally solved this problem. His design enables the exterior of the pontoon, directly opposite the photovoltaic cell mounting site, to remain beneath the liquid level for a wide range of sun elevation alignment angles, some of which are specified in the claims. In an exemplary embodiment, he used a combination of a special shape for the pontoon that permitted the photovoltaic cell to be mounted in a well asymmetrically formed on one side of the pontoon (as seen in cross section, see Figs 4-6), in combination with a lens that focuses the incoming sunlight asymmetrically with respect to the sunlight it accepts.

Another important claimed feature is a shadow-toleration feature that prevents significant non-uniformity of illumination of a photovoltaic cell receiving light from a lens receiving region that

itself is partly shadowed. As may be seen in Figs 4-6, immediately adjacent pontoons are progressively shadowed by their neighbor as both pontoons are rotated about their longitudinal axes. The inventor describes several different mechanisms to achieve "shadow tolerance," including a variety of suitable lens fabrication designs, and also photovoltaic cell fabrication designs.

VII.A.3 Primary Reasons Rejection of the Independent Claims Is Believed Improper

The rejection of independent Claims 1 and 8 over Cluff in view of Laing is improper for several reasons. First, the prior art represented by these references does not include any teaching of an important limitation that is present in both claims, and thus the combination cannot support *prima facie* obviousness of these claims. Second, solutions from one of the two references generally could not be applied to solve problems applicable to the other, due to the different physical constraints imposed by their very different principles of operation. Third, a skilled person would not look to the single-axis tracking system taught by Laing for solutions to problems with two-axis tracking systems such as Cluff's, because Laing very expressly teaches away from two-axis tracking systems. Finally, examination of the corresponding PCT application by US Examiner Diamond, who concludes that nearly identical claims are inventive over the identical prior art references, is evidence that the Examiner's rejection is improper.

VII.A.3.a Neither Cluff nor Laing Suggest Cooling as Claimed

Contrary to the contention of the Examiner, Laing does not teach the cooling feature required by Claims 1 and 8. The Appellant believes that the Examiner has most likely misconstrued the precise requirements of the cooling feature, apparently ignoring the essential term of cooperation "through." The Appellant's belief is based on the observation that the Examiner's statement in support of the rejection does not even allege that Laing teaches the required cooling. The Examiner's statement in support of the rejection , however, may be consistent with some confusing disclosure of Laing, and may be assumed correct *arguendo* for most purposes.

Claim 1 recites in part: "wherein the liquid bath is a coolant that provides primary cooling of the conversion device through thermal contact with an exterior of the support structure." Thus, primary cooling may be, for example, via, or as a result of, or by means of thermal contact of the coolant to an exterior of the support structure (pontoon). This "cooling element" may be properly

construed various ways, but the construction apparently imposed by the Examiner is not reasonable. The Examiner appears to construe the element as meaning "the liquid bath is a coolant that provides primary cooling of the conversion device" and "the coolant is in thermal contact with an exterior of the support structure." This is a case in which ignoring a single word ("through") in an element makes a radical difference in the construed meaning of the element. Remarks set forth hereinbelow provide dictionary definitions to further buttress the Appellant's demonstration of proper construction of the cooling element, as contrasted with the improper construction apparently imposed by the Examiner.

The Examiner's statement in support of the rejection asserts (Final Rejection, page 8, first full paragraph): "Cluff discloses the liquid bath/pool (34)(col.3; lines:44-47) that is in contact with an exterior of the support structure (32)(Figure 1 & col. 3; lines:21-26), but fails to disclose the liquid bath as the coolant." The rejection is muddled by the fact that item 32is not itself a solar collector, but rather is a large floating platform above which many collectors are disposed (Cluff, col. 3 lines 34-60), and none of the actual solar panels (40) mounted atop the support structure (32) touch the liquid bath at all (Cluff, col. 4 lines 39-45 and Figures 1, 7). While the Appellant finds better support for the Examiner's assertions in Figure 13, it is often impossible to address the Examiner's grounds for rejection head-on because they are so inapposite.

The Examiner's support statement further asserts that Laing includes disclosure of the elements that the Examiner acknowledges are not shown by Cluff. The Examiner's statement of support in this regard is nearly incomprehensible, which is understandable because the disclosure of Laing upon which it is based is similarly incomprehensible. The best understanding of the undersigned is that the Examiner intends to convey that Laing discloses the cooling fluid circulating through the pond (Final Rejection, page 8, first full paragraph, to page 9 line 2). Although this contention is believed to misrepresent the disclosure of Laing, even if it is assumed true *arguendo* Laing and Cluff still fail to disclose all the significant elements required by Claims 1 and 8, and thus fail to establish *prima facie* obviousness for either Claim 1 or Claim 8. Physical contact of the cooling liquid to the structure's exterior, which the Examiner seems to suggest Laing discloses, would entail thermal contact, but as described it would not be thermal contact that would provide primary cooling of the photovoltaic cell, as required.

Cluff only teaches cooling concentrating photovoltaic cells by means of cooling liquid forced through a channel or tube that runs close to the photovoltaic cell. This conclusion is supported by an detailed analysis of cooling in the Cluff reference set forth in a paper entitled "Interview Summary and Supplemental Cluff Analysis" that was submitted to Examiner Hall by facsimile on April 9, 2008, a copy of which is attached as listed in subsection *X. EVIDENCE APPENDIX*. The Examiner requested the analysis, which occupies substantially all of pages 2-5 of the indicated paper and is hereby incorporated herein by reference.

For cooling photovoltaic cells, Laing only teaches a technique substantially similar to the one described in Cluff: forcing coolant through a tube near the cells. Laing states (col. 3 lines 8-10, underlining added for emphasis): "The energy converter has to be in good contact with a coolant which will <u>flow through a pipe</u> forming a unit with the energy converter." This may be seen in Figure 5 of Laing, which shows (col. 6 lines 25-27): "the photovoltaic cell 53 forms a unit with cooling water pipe 54." Photovoltaic cells 73 and 73' are shown similarly configured in Figures 7 and 8b, respectively, and no contrary teaching is seen in Laing.

Even if it is assumed *arguendo* that Laing discloses that the coolant liquid, which cools the photovoltaic cells by flowing through a pipe in contact with the cells, is circulated into the supporting pond, where it will inevitably contact the exterior of the support structure, any such thermal contact in Laing would be incidental, and would not be operative to provide primary cooling of the conversion device. Instead, in Laing primary cooling of the conversion device is accomplished through <u>thermal contact between the coolant liquid and an interior wall of a coolant tube</u> attached to the conversion device. Thus, the cooling disclosed in Laing does not satisfy the requirement of Claim 1 that "the liquid bath is a coolant that provides primary cooling of the conversion device <u>through</u> thermal contact with an exterior of the support structure." Accordingly, neither Laing nor Cluff, nor the combination of the two, discloses the cooling element of Claim 1. For the same reasons, neither discloses the similar cooling requirement of Claim 8.

<u>VII.A.3.b Cluff Would Not Be Combined With Laing In Respect of Relevant Cooling Features</u>

Some aspects of pontoon solar collectors could be designed similarly irrespective of whether the principle of operation relies on single-axis tracking, or two-axis tracking. However, most aspects

of pontoon solar collector design will vary greatly depending upon the basic alignment principle of operation that is employed. All practical solar collection systems will employ pontoon collector units in an array. In such array, single-axis tracking pontoons do not move with respect to each other, or with respect to the plane of the supporting pond. Instead, the pontoons always have the same zero rotation with respect to the pond surface, and move only as a unit with other pontoons of the array so that all longitudinal axes of the pontoons align to the azimuth of the sun. In contrast, two-axis tracking pontoons always move with respect to each laterally adjacent pontoon and with respect to the plane of the supporting pond. The longitudinal axes of two-axis tracking pontoons are oriented perpendicularly compared to the longitudinal axes of single-axis tracking pontoons. In order for two-axis pontoons to align to the sun, they must be rotated about their longitudinal axes to align to the sun elevation, and this can only be successful if the longitudinal axes are aligned perpendicular to the azimuth of the sun.

A two-axis tracking pontoon should be capable of rotating about its longitudinal axis over an angular range exceeding sixty degrees from vertical, in order to be aligned to the sun over the most useful sun elevations. Any photovoltaic cell cooling technique employed in a two-axis tracking pontoon is therefore subject to physical limitations that simply do not apply to single-axis tracking pontoons. In particular: it would be one thing to dispose a photovoltaic cell within a single-axis tracking pontoon such that heat can be transferred to an external part of the pontoon that is in contact with the water. The pontoon has a fixed relationship to the water, so no relative movement need be tolerated. However, it is a vastly more difficult matter to design a photovoltaic mounting site in a two-axis tracking pontoon such that the exterior of the pontoon near the cell remains in full contact with the support pond over a wide range of rotational positions.

The preceding paragraph sets forth one particularly pertinent example as to why designs for single-axis tracking pontoons will not generally be suitable for use with two-axis tracking pontoons. However, there are many other examples of features that are not generally suitable for both single- and two-axis tracking operation, including most lens and light alignment features, as well as general mounting techniques. All of these features are highly dependent on the basic principle of operation of a solar collection pontoon system in which they are to be employed.

For the foregoing reasons, even a person of skill in the art will generally not be able to solve a problem (such as cooling or alignment) for two-axis tracking pontoons using a solution developed for s single-axis tracking pontoon. In general, the solution will only work if the principle of operation of the pontoon is changed, which would render it unsuitable for its purpose. Because Cluff teaches two-axis tracking pontoons, and Laing teaches single-axis tracking pontoons, solutions in Laing will generally not be applicable to problems faced by two-axis tracking pontoons such as Cluff and those of the Appellant.

Yet further, as set forth in detail subsequently, Laing expressly disparages and teaches away from two-axis tracking pontoon solar collection systems. As such, a skilled person would not look to Laing for solutions to problems faced by two-axis tracking pontoon systems.

VII.A.3.c Previous Favorable Examination of Rejected Claims

The patentable distinction of both of these cooling and shadow-tolerance features was recognized by US Patent Examiner Alan Diamond when he performed an International Preliminary Examination of the PCT application corresponding to the subject application (PCT application PCT/US02/32550 published 04/17/2003 with International Search Report as WO 03/032404). Examiner Diamond initially held that claims 1-40 of the corresponding PCT application lacked novelty over Cluff (PCT Written Opinion issued 22 August 2003 in respect of PCT/US02/32550). The Appellant acknowledged that the independent claims were overbroad, but urged that each dependent claim included a limitation that was not taught, disclosed or fairly suggested by Cluff (Reply to Written Opinion filed 22 October 2003, pages 2-4).

Examiner Diamond considered the Appellant's arguments in full view of Laing, which was one of only four references that he cited as relevant to claims 1-40, which include Claims 2 and 23 that correspond to independent Claims 1 and 8 as currently pending in the subject application (International Search Report included in WO 03/032404, the corresponding PCT application as published 17 April 2003). Indeed, of the four references cited as relevant, three are US patents issued to first-named inventor John Laing (US 5,286,305; US 5,445,177 "Laing;" and US 5,665,174), each of which disclose pontoon solar collectors that operate on the principle of single-axis tracking. Appropriately, in view of the completely different principle of operation compared to

the two-axis tracking taught by the Appellant and by Cluff, Examiner Diamond concluded that those three patents issued to Laing were merely "A" references, *i.e.*, he did not consider them to be particularly relevant to any claim.

Examiner Diamond ultimately concluded that dependent Claims 2 and 23 of the corresponding PCT application, which correspond closely to independent Claims 1 and 8 of the subject application as currently pending, were inventive over Cluff. He undeniably made this determination in clear view of Laing, considering that the Laing reference is one of only four references that Examiner Diamond cited as relevant to Claims 1-40.

VII.B. REJECTION OF INDEPENDENT CLAIMS 1 & 8 UNDER 35 USC § 103

Independent Claims 1 and 8 stand rejected as obvious over Cluff in view of Laing (section 6, page 7 of the Final Rejection, as supported on pages 7-8 and 10-11, respectively). Remarks set forth below in subsection VII.B.3 demonstrate that this ground of rejection is improper because a skilled person would not, and likely could not, modify Cluff in accordance with a single-axis tracking system solution in Laing to overcome a problem with a two-axis tracking system such as set forth in Cluff. First, however, the following remarks demonstrate that the rejection is improper because the two cited references, even if combined, fail to suggest all of the significant limitations recited in either Claim 1 or Claim 8. Examiner Diamond's favorable International Preliminary Examination Report supports the Appellant's contentions.

KSR v. TELEFLEX, 127 S. Ct. 1727; 167 L. Ed. 2d 705; 82 U.S.P.Q.2D 1385 (S.Ct. 2007) has reset the law for finding obviousness, such that it is once again properly determined by reference to Graham factual analysis. It also reiterates various principles of obviousness analysis. For example, it reminds us that finding each element in the prior art is a basic requirement for establishing obviousness of a claim, stating: "The TSM test captures a helpful insight: A patent composed of several elements is not proved obvious merely by demonstrating that each element was, independently, known in the prior art." (*id.*, 167 L. Ed. 2nd 705, 712)

However, the issue resolved in *KSR v. Teleflex* are legal in nature, because in that case "[T]he prior art's content, the patent claim's scope, and the level of ordinary skill in the art [were] not in material dispute." (*id.*, 167 L. Ed. 2nd 705, 714). The issues of the present appeal, by contrast, are

predominantly questions of fact, and in particular are questions of the content of the prior art cited by the Examiner, and/or questions of the scope of the rejected claims. As noted in the preceding paragraph, to be rendered obvious each of the elements of a claim must be shown to exist in the prior art. Each claim pending in the subject application stands rejected under 35 USC 103, but it is respectfully submitted that as to each claim such basic requirement for establishing *prima facie* obviousness is not met. In some cases the prior art does not show what the Examiner indicates and apparently believes that it shows. In other cases, the prior art may or may not show the features asserted by the Examiner, but such features do not in any event match the features required by the claims.

The arguments set forth below are primarily factual. Upon showing that the prior art cited by the Examiner fails in a material way to disclose, teach or suggest all of the limitations of a claim, the argument summarily asserts that the rejection based on such prior art is accordingly unwarranted. This comports with the basic requirements for finding obviousness, as remarked upon above.

VII.B.1 Appellant's Cooling Solution Compared to Cooling Taught By Laing

Cooling As Taught by the Appellant

"Concentrating photovoltaics" are semiconductor devices that typically receive sun concentrated 300 to 500 times. Under such intense radiation they will quickly exceed survival temperatures and be destroyed if they are not adequately cooled. Both Cluff and Laing teach only one mechanism to provide such cooling: forcing cooling liquid through a tube near the photovoltaic device. This solution has several drawbacks: (1) a water-tight channel must be provided near the photovoltaic device to carry the cooling liquid, which is a construction difficulty; (2) a pump must be provided to force the liquid through such channel, which requires external connections and operating energy; and (3) because failure of the cooling system will be catastrophic to the devices, the system must be made very reliable.

The Appellant determined to invent a cooling method that (a) would not fail catastrophically in the event of a failure such as of a pump or a tube blockage, and (b) would work over the full range of rotation of a two-axis tracking pontoon solar collection system. Design goal (a) may be achieved by a system that can operate passively; and this can be done if the heat can be conducted passively

from the photovoltaic cell to the liquid bath in which the pontoons float with sufficiently low thermal impedance. Design goal (b), however, further constrains the possibilities such that the obvious places where the photovoltaic cell might be disposed within the pontoon will not work.

The Appellant's solution can be visualized by consideration of the cross sectional views of exemplary pontoons that are shown in Figures 4-6 of the subject application. Figure 6 shows a pontoon rotated to accept sun from a low elevation. Location 96 is flat region suitable for mounting a photovoltaic cell (as may be seen more clearly in Figure 3). In this exemplary embodiment, the cell is just on the inside of an exterior wall that is made of a heat conductive material such as aluminum. The heat from the photovoltaic cell readily travels through the thin wall to the exterior surface of the pontoon; and because the pontoon is cunningly shaped to ensure that it is so, the exterior of the pontoon at the location 96 of the cell remains <u>below the surface of the supporting liquid pond throughout the operating elevation range of the pontoon</u>. As such, the pond is able to passively conduct the heat away from the cell over a wide range of rotational angles of the pontoon.

Describing Figure 6, paragraph 63 recites in part (underlining added for emphasis):

> 063 Heat derived from the concentrated sunlight could quickly damage the photovoltaic cell 100 or significantly reduce is efficiency if not managed properly. The photovoltaic cell 100 is attached to a thermally conductive heat exchange element 96 of the pontoon solar collector 30 in a method that enables the <u>heat absorbed by the cell 100 to be transferred into the heat exchange element 96 of the pontoon solar collector 30, where the heat can then dissipate into the surrounding pond water 22</u>.

A cursory glance at Figures 4 and 6 will reveal that the "heat exchange element 96" must therefore be between the photovoltaic conversion device 100 and the outside of the pontoon 26. Figure 3 shows exemplary element 96 more clearly as being simply the bottom of the trough-shaped portion of the pontoon, upon which the conversion devices are mounted. As described in the subject application (¶ 73 pg. 17 lines 16-17): "Photovoltaic cell 144 would be placed in thermal contact with the heat exchange element 96 contained in Fig. 3, when applied to the pontoon solar collector 30." As may be readily seen, such cooling is very direct, potentially entirely passive, and does not require forcing coolant through a tube, thus solving the three problems set forth above in subsection *VII.A.1 Introduction to the Prior Art and the Problems.*

Cooling As Taught by the Laing reference

Laing teaches cooling the photovoltaics by forcing liquid through a nearby conduit. Laing states (col. 3 lines 8-10): "The energy converter has to be in good contact with a coolant which will flow through a pipe forming a unit with the energy converter." An example may be seen in Figure 5 of Laing, which shows (col. 6 lines 25-27): "the photovoltaic cell 53 forms a unit with cooling water pipe 54." Photovoltaic cell 73 of Figure 7 (col. 7 line 34) is atop a vacuum insulated cooling pipe (col. 7 lines 8-13). Figure 8b apparently shows a photovoltaic cell 73' atop a cooling pipe, and other features as shown in Figure 7 (col. 8 lines 1-2). No cooling mechanism is seen in Laing that does not entail cooling conversion devices through close contact with a tube through which coolant is forced.

As has been stated elsewhere, it may be assumed *arguendo* that Laing circulates the coolant liquid through the pond so that it touches an exterior of the support structure (pontoon). However, it is not at all clear that Laing in fact does suggest such use of the support pond liquid as coolant. The relevant description is set forth in Laing (col. 8 line 56 to col. 9 line 11). There, the suggestion that the coolant may be transported to a remote heat utilizing system (col. 9 lines 3-11) casts particular doubt on the Examiner's apparent conclusion that the coolant is mixed with the pond. In view of the disclosure in col. 9, it seems more likely that Figure 11b illustrates a system of piping and channeling by means of which the coolant remains segregated from the "pond" liquid that supports the pontoons so that the heated liquid may be used for other purposes.

Even if the coolant were circulated within the pond such that it touched the exterior of the support structure, such touching or thermal contact between the coolant liquid and the structure exterior would be merely incidental to the process of cooling the conversion cells. It would not constitute an example of "primary cooling through thermal contact between coolant and an exterior of the pontoon." To be sure, the conversion cells in Laing are cooled primarily by coolant, but it is through thermal contact between the coolant and an interior of the coolant pipe.

VII.B.2 Cluff and Laing Fail to Disclose the "Cooling" Element of Claims 1 and 8

Proper construction of the "cooling" element of Claims 1 and 8

The "cooling" element is set forth in Claims 1 and 8 as follows (underlining added for emphasis):

> 1: "wherein the liquid bath is a coolant that provides primary cooling of the conversion device through thermal contact with an exterior of the support structure."
> 8: "(f) cooling the conversion device primarily through thermal contact between the liquid bath and an exterior of the support structure."

"Cooling primarily through thermal contact between the liquid bath and an exterior of the support structure" is something that is done by the exemplary embodiment described by the Appellant as illustrated in Figures 4-6. The meaning of "through" is readily understood in the context of the claim, with any ambiguity resolvable by considering the language in view of the specification of the subject application.

In the claim elements set forth above, "through" is used as a preposition. The following relevant definitions of "through" are drawn from *Webster's Encyclopedic Unabridged Dictionary of the English Language*, © 1989 dilithium Press, Ltd. There, definition 4 of "through" is: "over the surface of, by way of, or within the limits or medium of: *to travel through a country; He flies through the air with the greatest of ease.*" Definition 9 (*id.*) is: "by the means or instrumentality of; by the way or agency of: *It was through him they found out.*" This is, of course, what the reader would naturally understand from the cited language from Claims 1 and 8, particularly when properly considered in view of the specification, including Figures 4-6 and the associated description.

Examiner's construction of the "cooling" element of Claims 1 and 8

Unfortunately, the Examiner does not seem to have construed Claims 1 and 8 as requiring the heat to travel through the wall of the pontoon, or the cooling to be effected by means of thermal contact between the exterior of the pontoon and the liquid bath, or in any other way that might reasonably comport with the actual language of the "cooling" elements, including the cooperation term "through." Instead, the Examiner seems to have concluded that this cooling feature requires

only two unrelated conditions: (1) that the photovoltaic cell be cooled by means of a liquid; and (2) that the cooling liquid touch the exterior of the pontoon.

The Examiner's construction of this element may be deduced by consideration of her statement in support of the rejection. To support the rejection, Examiner Hall states (page 8 of "the Final Rejection," Office Action issued November 26, 2007 that finally rejects the subject application, underlining added for emphasis):

> Cluff disclose [sic] the liquid bath/pool (34) (col.3; lines: 44-47) that <u>is in contact with an exterior of the support structure</u> (32) (Figure 1 & col. 3; lines: 21-26), but fails to disclose <u>the liquid bath as the coolant</u>.

Examiner Hall goes on to show that Laing teaches pumping the cooling liquid from the pond, through the pontoon cooling channels. The Examiner seems to conclude that the coolant is circulated back into the pond where it would be in contact with the exterior of the pontoon. (This is the Appellant's best interpretation of the paragraph bridging pages 8-9 of the final rejection.)

The cooling system taught in Laing is the same as the cooling system taught by Cluff, *i.e.*, cooling liquid is pumped through a tube or passage that runs near the photovoltaic cell; however, in Laing the Examiner apparently contends that the coolant is circulated through the pond. If the Examiner is correct in this regard (which the Appellant does not acknowledge), then the photovoltaic cell is cooled by means of a cooling liquid, and the cooling liquid contacts an exterior of the pontoon, as asserted by the Examiner's support for the rejections of Claims 1 and 8.

<u>Statement of Support for Rejection Does Not Support prima facie obviousness</u>

Even assuming *arguendo* that the coolant liquid of Laing is circulated through the pond, as the Examiner seems to suggest, such cooling system is still in no way an example of the "cooling" element required by Claim 1 or Claim 8. Cooling in Laing, even with such an assumption, does not occur "primarily through thermal contact between the liquid bath and an exterior of the support structure" as required by Claim 8, or similarly by Claim 1. Indeed, the Examiner's statement of support for the rejection does not even allege that the cooling in Laing occurs "primarily through thermal contact between the liquid bath and an exterior of the support structure." Instead, it alleges that the pond liquid is a coolant, and that it touches an exterior of the support structure, which is far

from the same thing. Thus, even if the Examiner's statement of support for the rejection is entirely correct, the rejection still fails to render obvious either Claims 1 or Claim 8 as presently pending.

Even if the pond liquid *arguendo* provides primary cooling of the photovoltaic, it does not do so "through contact with an exterior of the pontoon." To the contrary, any such contact is incidental, and does not provide primary cooling. Primary cooling is instead achieved by thermal contact between the liquid and the inside of the cooling tubes.

The Appellant believes that the Examiner has incorrectly construed the meaning of the "cooling" element of each independent claim, but acknowledges that even though such belief explains the Examiner's conclusion and is consistent with the Examiner's statement in support of the rejection, it could nonetheless be mistaken. What is certain, however, is that neither Cluff nor Laing teaches, discloses or fairly suggests the limitation defined by the quoted cooling elements of Claims 1 and 8, when that element is properly construed, as it must be, according to the plain meaning of the terms, particularly when properly viewed in light of the specification. As such, the two cited references both fail to suggest this important limitation of Claims 1 and 8, and therefore even if combined these references cannot support *prima facie* obviousness of either of these claims. It is respectfully submitted that this rejection of Claims 1 and 8 is therefore improper, and the panel is accordingly respectfully requested to reverse the Examiner's rejection of Claims 1 and 8.

VII.B.3 Genequand cannot remedy Cluff & Laing omissions in respect of Claims 1 & 8

The Examiner cites Genequand (US 4,238,246) (section 7, pg. 12 of the Final Rejection) as teaching or suggesting claimed features. For completeness, the Appellant observes that Genequand cannot remedy the omissions of Cluff and Laing in respect of the cooling elements of Claims 1 and 8. Genequand is narrowly focused on "composite concentrating lenses," and includes no disclosure that is even remotely relevant to the cooling feature required by Claims 1 and 8. As such, Genequand cannot remedy the failings of Cluff and Laing in that regard. That is neither surprising nor controversial, because the Examiner does not even cite Genequand for such subject matter, but its absence is noted for completeness. Only Cluff, Laing and Genequand are cited against any of the pending claims, and the failure of Genequand completes a demonstration that all of the cited references, even taken together, fail to teach the cooling element of either of Claims 1 or 8.

VII.B.4 Cluff Would Not Likely Be Modified to Incorporate Laing Cooling Features

There is no cooling feature in Laing that is an example of the cooling limitation set forth in independent Claims 1 or 8, and as such the following remarks are necessarily conjectural, and cannot be applied to a specific example of cooling in Laing.

Even if, *arguendo*, Laing described cooling as required by the last element of Claims 1 or 8, Cluff in view of Laing would still most probably not render obvious either Claim 1 or Claim 8. A pontoon based on elements of both Cluff and Laing would have to satisfy the needs of two-axis tracking pontoons. A cooling feature designed for the single-axis tracking of Laing is unlikely to be compatible with the necessary two-axis tracking of the subject application, precisely because their principles of operation are so contrary.

Changing the Principle of Operation

MPEP § 2143.01 states: "If the proposed modification or combination of the prior art would change the principle of operation of the prior art invention being modified, then the teachings of the references are not sufficient to render the claims prima facie obvious." *In re Ratti*, 270 F.2d 810, 123 USPQ 349 (CCPA 1959) (Claims were directed to an oil seal comprising a bore engaging portion with outwardly biased resilient spring fingers inserted in a resilient sealing member. The primary reference relied upon in a rejection based on a combination of references disclosed an oil seal wherein the bore engaging portion was reinforced by a cylindrical sheet metal casing. Patentee taught the device required rigidity for operation, whereas the claimed invention required resiliency. The court reversed the rejection holding the "suggested combination of references would require a substantial reconstruction and redesign of the elements shown in [the primary reference] as well as a change in the basic principle under which the [primary reference] construction was designed to operate." *id.*, 270 F.2d at 813, 123 USPQ at 352.).

As has been noted, the constraints on solar collection pontoons designed for single-axis tracking are extremely different from the constraints on solar collection pontoons designed for two-axis tracking. The former do not move with respect to each other, or with respect to the supporting liquid, yet the latter must move with respect to each other, and also with respect to the supporting liquid. The former must accept insolation arriving at constantly changing angles with respect to the

solar collection pontoon, while the latter operates at a fixed angle to the insolation. While some features may not be affected by such drastic differences in operation, most will be strongly affected, and it will be clear that the finding of the *In re Ratti* court are entirely apposite: The court reversed the rejection holding the "suggested combination of references would require a substantial reconstruction and redesign of the elements shown in [the primary reference] as well as a change in the basic principle under which the [primary reference] construction was designed to operate."

Precedent exists distinguishing *Ratti*, such as *In re Umbarger*, 407 F.2d 425, 430-31, 160 USPQ 734, 738 (CCPA 1959). However, a cooling feature such as required by the last element of Claims 1 and 8, which relies upon a relationship between the photovoltaic cell mounting and the liquid bath must clearly be much differently designed in a system that must move over a wide rotational angle with respect to a surface of the bath, as compared to a system that does not move in that respect. The very asymmetric and unusual shape of the pontoon at the heat exchanger/ conversion device mounting surface (96, Figures 3-4 and 6) attests to the difficulty of designing a pontoon that will maintain the conversion device mounting region sufficiently in contact with the liquid bath.

It is respectfully submitted that the uniqueness of the Appellant's exemplary embodiment reflects the very creative design necessary to accommodate the constraints imposed by the need to rotate the pontoon over a wide range about its longitudinal axis. Because such rotational requirements do not constrain a designer of single-axis tracking pontoons, such designer is extremely unlikely to have arrived at a design of such a cooling feature (as defined in Claim 1 or Claim 8) that is also suitable for the greater constraints of two-axis tracking pontoons.

Accordingly, if a cooling feature satisfying the last element of Claims 1 and/or 8 existed in a pontoon designed for single-axis tracking (having a fixed orientation to the pond surface), the very different constraints on pontoons that must change such orientation over a wide range would most likely create a circumstance analogous to that described in *In re Ratti*. That is, it is very likely that adapting such a feature from a single-axis design reference to a two-axis design "would require a substantial reconstruction and redesign of the elements shown in [the single-axis design reference] as

well as a change in the basic principle under which the [single-axis design reference] construction was designed to operate."

Rendering Prior Art Unsatisfactory for its Intended Purpose

Moreover, section V of MPEP 2143.01 states that there is no suggestion or motivation to make a modification that would render the prior art unsatisfactory for its intended purpose, citing *In re Gordon*, 733 F.2d 900, 221 USPQ 1125 (Fed. Cir. 1984) (Claimed device was a blood filter assembly for use during medical procedures wherein both the inlet and outlet for the blood were located at the bottom end of the filter assembly, and wherein a gas vent was present at the top of the filter assembly. The prior art reference taught a liquid strainer for removing dirt and water from gasoline and other light oils wherein the inlet and outlet were at the top of the device, and wherein a pet-cock (stopcock) was located at the bottom of the device for periodically removing the collected dirt and water. The reference further taught that the separation is assisted by gravity. The Board concluded the claims were prima facie obvious, reasoning that it would have been obvious to turn the reference device upside down. The court reversed, finding that if the prior art device was turned upside down it would be inoperable for its intended purpose because the gasoline to be filtered would be trapped at the top, the water and heavier oils sought to be separated would flow out of the outlet instead of the purified gasoline, and the screen would become clogged.).

Due to the serious incompatibility between single-axis tracking and two-axis tracking pontoon collection systems, it is not unlikely that modifying Cluff in accordance with cooling features designed for a single-axis tracking system such as Laing disclosure regarding cooling features in Laing would render Cluff unsatisfactory for its intended purpose.

VII.C REJECTION OF CLAIMS 2-4, 7, 9-10 AND 13-14 UNDER 35 USC § 103

The Examiner rejects Claims 2-4, 7, 9-10 and 13-14 as obvious over Cluff in view of Laing (Final Rejection, section 6, top of page 7). The remarks set forth below support a conclusion that each of Claims 2, 4, 7, 9 and 13-14 are patentably distinguished over the cited prior art irrespective of any patentable distinction provided by Claim 1 or Claim 8 from which such claim depends.

VII.C.1 Rejection of Claims 2 and 9

Claim 2 recites in part (underlining added for emphasis):

> wherein the photovoltaic mounting is on <u>an inside of an exterior wall</u> that in operation is in contact with the liquid bath at a point directly transverse the wall from a point of the mounting.

The Examiner asserts (Final Rejection, page 9, first full paragraph, underlining added for emphasis):

> With respect to claim 2, Cluff discloses that the liquid bath (34) in Figure 1, wherein the photovoltaic mounting (43) which is encapsulated [*sic*] the lens structure (40) is on an inside of an exterior wall as shown in Figure 1 & 4, that in operation is in contact with the liquid bath/pool (34) at a point directly transverse the wall from a point of the mounting as shown in Figure 1.

The Appellant respectfully disagrees with the Examiner. The structures of Figures 1-8, inclusive, are neither shown nor intended for submersion in water. Instead, the collection structures are supported upon a platform (32) that floats on the water, keeping the collector structures entirely out of the water (*e.g.*, col. 3 lines 34-60). As such, the exterior wall of the photovoltaic mounting structure is not in contact with a bath/pool at all, and thus <u>cannot</u> satisfy the requirement set forth in Claim 2.

Claim 9 recites in part (underlining added for emphasis):

> cooling the conversion device primarily through thermal contact between the liquid bath and an exterior of a wall of the support structure, <u>the wall having an interior upon which the conversion device is mounted opposite an expected area of contact with the liquid bath</u>, such that in operation at least one line perpendicular to the wall traverses the conversion device mounting on an immediate inside of the wall and the liquid bath on an immediate outside of the wall.

In support of the outstanding rejection of Claim 9, the Examiner sets forth the following statement (Final Rejection, page 11, second paragraph, underlining and bracketed capital letters added for emphasis):

> In regard to claim 9, Cluff discloses wherein the [A] <u>support structure (32), lens (33) and conversion device (43) are part of a first collection pontoon/floats</u> and the liquid bath (34) is a coolant bath having an average surface plane in Figure 1 comprising: [B] <u>cooling the conversion device (43) primarily through thermal contact between the liquid bath (34) and an exterior of the support structure (32)</u>. Cluff also discloses [C] <u>the wall (49) having an interior</u>

> (as shown in Figure 1 & 4) upon which the conversion device (43) is mounted opposite an expected area of contact with the liquid bath (34), such that in operation at least one line perpendicular to the wall traverses [D] the conversion device (43) mounting on an immediate inside of the wall (Figure 4) and the liquid bath (34) on an immediate outside of the wall (49) (col.6; lines: 3-10).

The Appellant must respectfully disagree with the contentions in the Examiner's statement of support. As to the underlined portion [A], the support structure (32) is not part of a first collection pontoon/float as asserted by the Examiner, but rather is simply a platform upon which solar collection structures may be disposed (Figures 1 & 7; col. 3 lines 34-60).

As to underlined portion [B], Cluff does not disclose cooling the conversion device (43) primarily through thermal contact between the liquid bath (34) and an exterior of the support structure (32), as there is no connection whatever between the conversion device (43), which is mounted in a collector panel (40) that is one of a plurality of such that are disposed atop the support structure (32) (Figures 1, col. 4 lines 39-41, and Figure 7). Being on top of the floating platform (32), the exterior of the solar collector panel (40) is never in contact with the liquid bath at all, thus precluding "cooling the conversion device (43) primarily through thermal contact between the liquid bath (34) and an exterior of the support structure (32)" as asserted by the Examiner. The Examiner has admitted this fact in the rejections of Claims 1 and 8, attributing the required cooling to a combination of Cluff and Laing. (Remarks set forth above in subsection *VII.B.2 Cluff and Laing Fail to Disclose the "Cooling" Element of Claims 1 and 8* demonstrate that Cluff and Laing, even combined, fail to disclose the required cooling.)

As to underlined portion [C], (49) is the top surface of the floating platform (32) (col. 6 lines 5-6) and is therefore not a wall of a solar collector as asserted by the Examiner; and it has no inside surface upon which collectors might be mounted. Elsewhere the Examiner has pointed to Figure 13, but it is also unavailing for this element. Not only does Figure 13 show no detail to support the Examiner's contention, Figures 15 and 16 show collector mounting sites 74 and 79 that are not interior surfaces of an exterior wall, and thus the only supported conclusion is that Figure 13 does not suggest the asserted limitation, even by implication.

As to underlined portion [D], Figure 4 is part of the solar energy collection system of Figures 1-8, in which the solar collectors (43) are disposed in collector panels (40) that are mounted on top of a floating platform (32) (col. 3 lines 34-60) and thus the liquid bath (34) is not on an immediate outside of the wall on which the collectors (43) are mounted, contrary to the assertion of the Examiner. Item (49) is not a wall, but is the top surface of the platform (32), and no collectors (43) are mounted on any side of such surface, contrary to the assertion of the Examiner. Figures 15 and 16 imply that no collectors (73, 51) are mounted on an immediate inside of a wall having the liquid bath on an immediate outside, even considering Figure 13.

For all the reasons set forth in this subsection, the Examiner's statements of support for the rejections of Claims 2 and 9 are incorrect in numerous ways, and fail to correctly demonstrate that Cluff teaches the limitations required by either Claim 2 or Claim 9. Neither other portions of Cluff, nor Laing, nor even Genequand, are believed to remedy the failure of those portions of Cluff pointed to by the Examiner in this regard. As such, Claims 2 and 9 are properly allowable over any combination of these references, irrespective of any patentable distinction that may be provided by Claim 1 or Claim 8, the respective independent claims. Therefore, the panel is respectfully requested to reverse the Examiner's rejections of Claims 2 and 9.

VII.C.2 Rejection of Claims 3 and 10

Claim 3 recites in part (underlining added for emphasis):

> the support structure is a first support structure, and is disposed in contact with a liquid bath in an array of support structures, substantially abutting adjacent support structures that each have an elevation rotation axis parallel to and in a plane with the elevation rotation axis of the first support structure.

In support of the rejection of Claim 3, the Examiner states (Final Rejection, page 9, second full paragraph, underlining added for emphasis):

> With respect to claim 3, Cluff discloses that the support structure (32) is a first support structure (32), and is disposed in contact with a liquid bath (34) in an array of support structures (40), substantially abutting adjacent support structures (40) that each have an elevation rotation axis parallel to and in a plane with the elevation rotation axis of the first support structure (32) in Figure 1.

The Examiner has conflated a platform (32) upon which solar collection panels (40) are mounted. The solar collection panels (40) themselves are not in contact with the pond. The platform (32) itself does not have an elevation rotation axis; instead it rotates only about a vertical axis, like a lazy susan (col. 3 line 34 - col. 4 line 24). The support structure is not "disposed in an array of support structures (40)," but rather has an array of solar collection panels (40) mounted upon it. The solar collection panels (40) are indeed analogous to the support structure referred to in Claim 3, except that they are at no time in contact with the pond. The support structure (32) does not correspond to any part of Claim 3 or Claim 10.

In respect of Claim 10, the Examiner relies on an assertion that the support structure (32) has an elevation axis (45) (Final Rejection page 12 first paragraph). The Examiner is again mistaken: item (45) is a motor (col. 4 lines 54-55). Support structure (32) has no elevation axis at all, as it is like a floating table. The elements identified by the Examiner simply do not match the elements required by Claim 10.

The reasons set forth by the Examiner to support this rejection are thus entirely incorrect. However, the particular feature recited in Claim 3, and that recited in Claim 10, may unintentionally read upon the solar collectors (61) of Figure 13 of Cluff. There, groups of four solar collectors (61) are abutted <u>in a line along their longitudinal axes</u>. Because such an arrangement was not considered, Claims 3 and 10 were written without regard to this possible arrangement. The Appellant therefore respectfully requests leave to amend Claims 3 and 10 to reduce the scope of the elements recited therein by requiring that the elevation rotation axes are "laterally separated" from, or "not in line" with, each other.

Claims 3 and 10, as currently pending, may stand or fall with Claim 1 or Claim 8, respectively, but if amended as requested above would further distinguish Cluff. Cluff must separate the solar collector structures from each other, as may be seen in Figures 1, 13 and 14. The Appellant need not provide such separation because he has overcome the problem of shadowing by adjacent solar collectors. It is only due to the Appellant's solution to this problem that lateral abutment of pontoons, as required by these claims, is practical in a two-axis tracking pontoon collection system.

VII.C.3 Rejection of Claim 4

Claim 4 recites in part (underlining added for emphasis):

> wherein light parallel to the incoming light axis that enters with uniform density across an entire surface of the lens exits the lens at angles with respect to the incoming light axis, an average of all such exiting light angles defining a light delivery axis, the light delivery axis having a significant non-zero angle with respect to the incoming light axis.

An incoming light axis of the lens that is substantially fixed to the support structure is defined for Claim 4 in Claim 1, and Claim 4 further defines a delivery (outgoing) light axis (based on an average of all exiting light angles). Importantly, the incoming light axis is not parallel to, but has a significant non-zero angle with respect to the delivery light axis. An example of such a feature is shown in Figure 4, as described in paragraph 63 as "asymmetric." Paragraph 63 discloses in pertinent part (underlining added for emphasis):

> 065 The focal point/line position of the roof lenses 24 may be made asymmetric to facilitate locating the photovoltaic cell 100 on a mounting region that remains in thermal contact with the pond cooling water 22 during low sun heights. "Asymmetric" focus is used to mean that the average exit angle of light that uniformly enters the lens face parallel to the incoming light axis (for which it is designed), as compared to the incoming light angle, is significantly non-zero. As shown (Fig. 4), the asymmetry angle between the incoming and average exiting angles is approximately 9 degrees; the asymmetry angle will vary, of course, depending upon the exact geometry of the pontoon.

In regard to Claim 4, the Examiner states (Final Rejection page 9 third full paragraph):

> With respect to claim 4, Cluff discloses that the light parallel to the incoming light axis that enters with uniform density across an entire surface of the lens exits the lens at angles/orienting with respect to the incoming light axis (col. 1; lines: 56-69), an average of all such exiting light angles defining a light delivery axis, the light delivery axis having a significant non-zero angle with respect to the incoming light axis (col. 4; lines: 66-69) in Figure 1.

Col. 1 lines 56-69 of Cluff set forth objects of the invention, including "to provide improved tracking both altitude and azimuth." That section includes nothing whatsoever about light exiting a lens having a non-zero angle with respect to light entering said lens. Col. 4 lines 66-69, in their entirety, recite:

"depending on the sun's rays through the use of the sensor to keep the reflective surfaces of the collectors perpendicular to the rays of the sun. Only one sensor and"

Neither of these sections of Cluff provides any disclosure or suggestion whatsoever in respect of a relationship between incoming and outgoing light angles of a lens, let alone suggesting any of the very specific requirements set forth in Claim 4. Thus, the portions of Cluff pointed to by the Examiner include absolutely nothing that is even closely related to the very specific requirements set forth in Claim 4. Nor is Cluff seen to provide any teaching, disclosure or suggestion of these features elsewhere. This conclusion is buttressed by the Examiner's admission, as noted in remarks set for below in respect to generally similar Claim 11, that Cluff fails to disclose the light delivery axis of the lens (Final Rejection, page 14 lines 6-8), which is an important part of the requirements of Claim 4.

Laing is not seen to remedy this failure of Cluff, and Genequand is also not seen to remedy this failure. A relevant analysis of Genequand in regard to generally similar requirements of Claim 11 is set forth in subsection *VII.D.3 Rejection of Claim 11* and incorporated here by reference. The analysis of Genequand demonstrates that Genequand also fails to disclose the features required by Claim 4. As such, it is respectfully submitted that none of the three references Cluff, Laing and Genequand discloses the required features.

The failure of any of the cited references to disclose the features required by Claim 4 requires a conclusion that Claim 4 is nonobvious and properly allowable over any combination of those three references, irrespective of the patentability of Claim 1 from which it depends. The panel is therefore respectfully requested to reverse the Examiner's rejection of Claim 4.

VII.C.4 Rejection of Claims 7 and 13

Claim 7 recites (underlining added for emphasis):

> The apparatus of Claim 1, wherein during operation the incoming light axis is aligned with a light source elevation angle, and the support structure floats in a coolant bath that has an average surface plane, the apparatus further comprising a device mounting site within the support structure, upon which a photovoltaic converter device is mounted, which during

> operation is below the coolant bath average surface plane for all light source elevation angles within 45 degrees from vertical.

Claim 13 sets forth requirements that are sufficiently similar to those of Claim 7 that the remarks set forth below, *mutatis mutandis*, can readily be seen to apply to Claim 13. Remarks specific to Claim 13 are also set forth following those directed to Claim 7.

The Examiner supports the outstanding rejection of Claim 13 by asserting (Final Rejection, pg. 9 last partial paragraph, underlining added for emphasis):

> In regard to claim 7, Cluff discloses that the incoming light axis is aligned with a light source elevation angle in Figure 1, and the support structure (32) floats in a coolant bath (34) that has an average surface plane (iv) a device (43) mounting site within the support structure (32), upon which a photovoltaic converter device (46) is mounted, which during operation is below the coolant bath (34) average surface plane for all light source elevation angles within 45 degrees from vertical in Figure 13 oriented at 45.

The Examiners statement of support for this rejection badly confuses the structure of Cluff. Item (32) of Cluff is a floating platform, like a large round table or dock (see Figures 1 and 7). While the support structure 32 floats in a bath, it is not a coolant bath but merely a support bath. More importantly, there is no photovoltaic converter device mounting site anywhere in or on platform 32 that is below water level at any time whatsoever, let alone "for all light source elevation angles within 45 degrees from vertical." All of the mounting sites are within the collection panels (40) that are mounted on top of support structure 32, and are thus not in the pond at all. The Examiner's statement of support for the rejection, as quoted above, thus entirely fails to describe any manner in which Cluff discloses the features required by Claim 7, or for generally similar Claim 13.

However, in section 5 of a "Response to Arguments" section (page 17 of the Final Rejection), the Examiner dismisses the Appellant's argument that none of the photovoltaics of Cluff are shown or described as being below a surface plane of the supporting bath by stating: "Figure 13 of Cluff, depicts the structure being partially disposed in the supporting bath/pool."

Figure 13 of Cluff entirely fails to support the outstanding rejection of Claims 7 and 13. It is true that Figure 13 shows pontoons (support structures) that are floating in a support pool. However, there is absolutely no illustration detail showing any device mounting site at all, no detail showing

that any device mounting site is ever below water level, let alone showing the vastly more restrictive requirement that the device mounting site remain below water level "for all light source elevation angles within 45 degrees from vertical," as required.

Yet further, the only figures of Cluff that show any detail of photovoltaic mounting sites with respect to water level, Figures 15 and 16, show that the mounting sites <u>are above the water level</u>, and it appears moreover that the mounting sites <u>will remain above the water level for all elevation angles</u>. Thus, Cluff not only fails to disclose the requirements set forth in Claims 7 and 13, but discloses <u>only</u> structure that appears to be diametrically opposite to the requirements of those claims.

Because Laing also fails to provide such disclosure, as does Genequand, the requirements of Claims 7 and 13 render those claims properly allowable over Cluff, even in combination with Laing and/or Genequand, irrespective of any patentable distinction provided by independent Claims 1 or 8, respectively. The Examiner's rejection of these claims is accordingly improper for these additional reasons, and the panel is therefore respectfully requested to reverse the Examiner's rejection of these claims.

Claim 13 recites (underlining added for emphasis):

> The method of Claim 8 wherein the liquid bath is a coolant bath having an average surface plane, the method further comprising <u>positioning the conversion device mounting site below the coolant bath average surface plane for all light source elevation angles within 45 degrees from vertical</u>.

As may be seen, Claim 13 is quite comparable to Claim 7, and the remarks set forth above with respect to Claim 7 apply to the rejection of Claim 13 *mutatis mutandis*.

The Examiner asserts (Final Rejection pg. 12 lines 6-8, underlining added for emphasis): "In regard to claim 13, Cluff discloses positioning the conversion device (43) mounting site below the coolant bath (24) average surface plane for all light source elevation angles within 45 degrees from vertical as showing [sic] Figure 13."

While the pontoons of Fig. 13 are indeed floating in the liquid bath as required, Cluff provides no detail whatsoever that could be construed as suggesting or teaching the features required

by Claim 13. Nor is there textual support: Figure 13 is described at col. 6 lines 40-47, which says nothing about photovoltaic mounting sites. However, Figure 15 shows detail of panels 65 of Figure 13. As may be seen, the water level (dotted line) is very low, far below the conversion device(s) 73 as would be true at most, if not all, angles in view of the thick, hollow walls between the devices 73 and the outside of the support structure 65. Thus, the Examiner's asserted support does not disclose the features required by Claim 13, nor does Cluff elsewhere suggest the requirements recited in Claim 13.

Laing and Genequand fail to remedy the failure for the reasons set forth above with respect to Claim 7. Accordingly, the Examiner's rejection of Claim 13 is improper at least by virtue of the fact that none of the cited references Cluff, Laing and Genequand disclose, teach or fairly suggest the requirements recited in Claim 13. As such, the panel is respectfully requested to reverse the Examiner as to the rejection of Claim 13.

VII.C.5 Rejection of Claim 14

Claim 14 requires in part: "incorporating a light source direction sensor within each pontoon." The Examiner points to Cluff, col.4, lines 58-64 as disclosing this element.

Cluff, col. 4 lines 58-64 describe an "altitude light sensing mechanism 47." However, at col. 4 lines 62-63, Cluff indicates that one sensor is needed per motor 45 that drives "screw means 46 which pivotally moves simultaneously all of the parallelly arranged panels ..." Thus, far from suggesting one light source direction sensor in each pontoon, as required, Cluff teaches using one sensor for "all of the parallelly arranged panels." Cluff therefore does not teach the requirement of Claim 14, but teaches the exact opposite. Neither Laing nor even Genequand can remedy the failure of Cluff to disclose these requirements, and accordingly Claim 14 is properly allowable over any combination of these three references, irrespective of the patentability of Claim 8 from which it depends. The panel is therefore respectfully requested to reverse the Examiner's rejection of Claim 14.

VII.D REJECTION OF CLAIMS 5-6 AND 11-12 UNDER 35 USC § 103

The Examiner rejects Claims 5-6 and 11-12 as obvious over Cluff in view of Laing and further in view of Genequand (Final Rejection, page 12, section 7).

VII.D.1 Rejection of Claim 5

Claim 5 recites in part (bracketed numerals and underlining added for reference):

> wherein [1] the receiving region of the lens is subject to shadowing that causes substantially non-uniform illumination of the receiving region of the lens, the apparatus further comprising a shadow toleration mechanism that coordinates light entering through the lens with each target photovoltaic conversion device to [2] avoid substantially non-uniform illumination of operating photovoltaic conversion devices due to such shadowing.

The Examiner acknowledges that Cluff fails to disclose the receiving region of the lens with a shadow toleration mechanism, but asserts that Genequand "discloses the receiving region of the lens (11) with a shadow toleration mechanism (col. 2; lines: 6-23) that coordinates light entering through the lens with target photovoltaic conversion device to avoid substantially non-uniform illumination of operating photovoltaic conversion devices due to such shadowing." (Final Rejection, page 12, last partial paragraph.) The Examiner does not point to any different part of Genequand.

Col. 2 lines 6-23 of Genequand includes most of the "Summary of the Invention" section. While the word "shadow" appears (line 21), it has nothing whatsoever to do with "shadow tolerance" or "shadow toleration" as set forth in Claim 5.

First, there is no shadowing in Genequand. The lens of Genequand is designed to avoid any shadowing (col. 2 lines 20-22, underlining added for emphasis): slats in a slide assembly "are spaced from each other in such a manner so as to not shadow an adjacent slide which is inclined at a slightly different angle." Thus, the lens of Genequand is designed so that it does not "shadow itself" internally. There is no suggestion anywhere in Genequand of any other sort of shadowing. Thus, Genequand immediately fails to comport with the requirements of Claim 5 (underlined portion [1] set forth above).

Second, even considering the shadowing of slats that Genequand expressly avoids, such shadowing would not "cause substantially nonuniform illumination of the receiving region of the

lens" as required (underlined portion [1] set forth above). The receiving region of the lens is defined in Claim 1(c), and is clearly where the light arrives at the lens. The shadowing mentioned in Genequand would be internal to the "lens," subsequent to the "receiving region." Thus Genequand fails to comport with the requirements for this second reason as well.

Cluff does not discuss or solve the shadowing problem, and Laing does not have any shadowing because the single-axis tracking principle of operation avoids shadowing. None of the references thus even acknowledge the problem, let alone provide a feature to solve the problem. As such, even if the references were combined, there is simply no disclosure in any of them of the features required by Claim 5. As such, the Examiner's rejection of Claim 5 over a combination of these three references is improper irrespective of any allowability of Claim 1 from which it depends. The panel is therefore respectfully requested to reverse the Examiner's rejection of Claim 5 for all of these reasons.

VII.D.2 Rejection of Claim 6, and Shadow Tolerance Generally

Claim 6 recites in part (underlining added for emphasis):

> The apparatus of Claim 1, further comprising a plurality of subregions of the lens that each receive light substantially parallel to the incoming light axis over a corresponding receiving subregion, wherein each subregion is configured to disperse the received light substantially uniformly over an entire surface of at least one corresponding target photovoltaic conversion device.

The Examiner concedes that Cluff fails to disclose a plurality of sub regions of the lens to target the photovoltaic conversion device, but asserts that Genequand discloses that feature. The Examiner reasonably asserts that Genequand discloses a conversion device and a plurality of sub regions of a lens. The Examiner errs, however, in asserting that Genequand teaches "wherein each sub region/slat (39) is configured to disperse the received light substantially uniformly over an entire surface of at least one corresponding target photovoltaic" (Final Rejection, page 13 lines 16-19). This contention is conclusively supported by a clear statement in Genequand, coupled with an accurate geometric analysis which is, regrettably, rather tedious. As such, the panel's patient and careful attention is respectfully requested for the following remarks.

Genequand teaches that all subsections of the lens are to be focused at the same focal point, describing (col. 2 lines 14-17, underlining added for emphasis): "a set of reflective slats, termed a slide assembly, installed in a frame and supported so as to reflect incident solar rays onto the <u>same focus</u> as <u>the</u> focus of the Fresnel lens are provided." These slide assemblies and the Fresnel (or other) lens comprise an entirety of the lens. As such, all subsections of the lens are focused at the same point.

Genequand provides a very useful figure to illustrate the following mathematically provable contention: when all parts of a lens focus incoming light on a single point, there is necessarily a one-to-one geometric correspondence between, first, a relative incidence point with respect to the lens of an incident light ray, and second, a relative location, within any plane perpendicular to the focal point vector, of the path of said incident light ray as it passes through the plane. (Ignoring random scattering effects does not impair the statistical validity of the points about distribution of incoming light). Such one-to-one correspondence is precisely that which enables lenses to be used to transfer images with precision, such as for projection purposes.

Define (r , Θ) as a radial position defined as an angle and a radius proportional to R, a maximum radius of the lens from a central point C of the lens. A photon arriving along the incoming light axis and incident at (r , Θ) will travel through any particular Plane perpendicular to the line between C and the single focal point F of the lens at a point (r' , Θ), where r' = r (d/FL), FL the focal length and d the distance along the focal line between F and C of the intersection between the line and the particular Plane.

The conclusion of that tedious mathematical explanation can readily be seen by following the dotted lines representing light rays that are shown in the figure of Genequand. Consider a random plane perpendicular to the focal line between C (which is near 11) and F, for example a plane P parallel to the lens that just touches the tops of segments 35 and 37. Notice that a light ray incident at point 13 travels down and intercepts P on the left side, while a light ray incident at the farthest right slat of slide unit 17 intercepts P on the far right. As may be seen, each light ray will traverse P at a point that is geometrically proportional to its incidence point on the lens.

Once that painful analysis is correctly digested, the following hypothetical will be readily understood. Suppose that the entire lens is uniformly illuminated, except no light is incident on the slide assembly 17. One will quickly realize that light will not uniformly traverse P, but rather will traverse P uniformly except substantially no light will traverse P between the two rightmost dotted lines.

That, then, is precisely the problem of shadowing a lens that is focused at a single point: the shadow is precisely *imaged* on the target (which is typically a plane a short distance above or below F), which is therefore by definition shadowed, or non-uniformly illuminated. Because shadowing a portion of the lens results in shadowing a geometrically proportional part of the target photovoltaic, damage will be done: at the least the photovoltaic will experience highly non-uniform illumination that will send its efficiency plummeting; at the worst it could paradoxically result in increased waste heat that could even overheat and destroy the converter cell.

We turn now to shadow tolerance, which can alleviate the described problem. Consider the following further hypothetical: imagine that the slats of slide assembly 17 are so configured that the dotted lines descend not to corresponding points on the right hand side of P, but rather to the tip of segment 35 and the tip of segment 37, respectively; and that light from slide assembly 17 is uniformly distributed between those points, which define the limit of the target for purposes of discussion. Now imagine that the same is true for the other three indicated slide assemblies, and for the Fresnel section in the center of the lens. In each case, the light is refracted (or reflected) such that light from the left side of any such subunit goes to the tip of 35, light from the right side of such subunit goes to 37, and everything is uniformly distributed in between.

Now, if the lens is uniformly illuminated except one subunit (for example, slide unit 17) is suddenly shadowed, the result is that the illumination through P remains entirely uniform, despite the shadowing of slide unit 17.

That is an example, though crude and in two dimensions, of shadow tolerance. As a practical matter the subunits would likely be made smaller, and/or would be shaped to conform to the contours of expected shadows. In most solar collector pontoons, for example, the shadow shape is predictable: it will start at an edge of the target and gradually progress across more and more of the

target. The trick is that so long as every subunit of the lens is focused not to a single point, but is configured instead such that the light from such subunit is dispersed uniformly over the target, then the total shadowing of any one subunit will not impair the uniformity of illumination of the target. That is the circumstance required by Claim 6, as remarked upon in more detail below. (Note that individual subunit light may be mapped to image on the target, and consequently partial shadowing of such subunit will degrade uniformity of target illumination. However, subunits can be made sufficiently small compared to the overall size of the lens that the effect of any one partly-shadowed subunit is negligible.)

For completeness, note that shadow tolerance, as defined for example in Claim 5, is merely a "mechanism that coordinates light entering through the lens with each target photovoltaic conversion device to avoid substantially non-uniform illumination of operating photovoltaic conversion devices due to such shadowing" of the receiving region of the lens. Shadow tolerance can be achieved by various means. For example, the lens may be left as an ordinary (*e.g.*, single-point focus) lens, but the target can be divided into subunits shaped according to expected shadow patterns on the target. That can be effected, for example, by electrically disconnecting subunits of the target that are shadowed, so that all operating portions of the target remain uniformly illuminated in spite of partial shadowing of the lens.

The Appellant truly appreciates any reader that has expended the time and effort to understand the foregoing explanation of the problem of shadowing and shadow tolerance mechanisms. These ideas are, of course, described in the subject application in great detail (for example, Fig. 7 as described in ¶ 66-67 pg. 15 lines 10-21 and Fig. 8 as described in ¶ 68-70 pg. 15 line 22 - pg. 16 line 16, but also ¶ 34 traversing pages 6-7, and ¶ 71-78 pg. 16 line 17 - pg. 19 line 11), but a lack of time to read such material is well understood. The reader is respectfully requested, however, to comprehend sufficient of the abbreviated description set forth above to fairly judge the claimed invention.

Moreover, the Appellant's representative, who can be reached at the number indicated on the transmittal letter accompanying this Brief, will be more than pleased to telephonically guide any interested party through the interesting geometric issues related to shadow tolerance.

In understanding the description set forth above, and/or the teaching of the subject application, it is believed that the reader will quickly understand that Genequand in no way teaches or inherently embodies the requirement set forth in Claim 6 for a lens with a plurality of subregions wherein "each subregion is configured to disperse the received light substantially uniformly over an entire surface of at least one corresponding target photovoltaic conversion device." That is because the lens of Genequand, as stated in Genequand (same focus, col. 2 lines 14-17), and like most lenses, is designed for single-point focus. A single-point focus lens is contrary to the requirements of Claim 6: as explained in the remarks set forth above, each subregion in a single-point focus lens disperses the light it receives only over a region of a target that corresponds to the particular subregion, not over any entire target.

VII.D.3 Rejection of Claim 11

Claim 11 recites in part (underlining added for emphasis):

> The method of Claim 8, wherein a light delivery axis is defined as a line that intersects the incoming light axis at a center of the lens and has an angle with respect to the incoming light axis that is equal to an average angle of light exiting the lens when such light entered the lens parallel to the incoming light axis and uniformly distributed over an entire surface of the lens, the method further comprising configuring the lens to have the light delivery axis at a significantly non-zero angle with respect to the incoming light axis.

As may be readily seen, the requirements set forth in Claim 11 are quite similar in effect, though in a different, method form, as the requirements set forth in Claim 4 as remarked upon above. As such, the remarks set forth in subsection *VII.C.3 Rejection of Claim 4* are incorporated here by reference for their relevance to the issues of Claim 11.

In support the outstanding rejection of Claim 11 over Cluff in view of Laing and further in view of Genequand, the Examiner concedes that Cluff fails to disclose the light delivery axis of the lens. Instead, the Examiner correctly asserts (Final Rejection, page 14 from line 9) that Genequand discloses alight delivery axis as defined by Claim 11. The Appellant agrees that such light delivery axis is determinable from the figure of Genequand: it is perpendicular to, and centered on, the receiving area of the lens. It is easy to visualize such axis, because it connects the center of the lens

to the center of the target (31). It may also be seen as the axis of the cone of light that aims for the focal point from each and every point of the lens. Were the light delivery axis not thus centered on the lens and perpendicular to it, the target would need to be disposed elsewhere, or else the light would miss the target.

The Appellant respectfully submits that the incoming light axis of Genequand is also readily determined to be perpendicular to the plane of the lens in view of the dotted lines representing light rays, which are all perpendicular to the lens on the side away from the target 31, and further in view of the description of following (aligning to) the sun at col. 2 lines 52-56.

Given that the incoming light axis and the light delivery axis are both perpendicular to the lens, it is respectfully submitted that these axes are therefore necessarily at zero degrees with respect to each other. As such, they are not at "a significant non-zero angle to each other" as required by Claim 11 and as asserted by the Examiner. Claim 11, like Claim 4, has accordingly been demonstrated to set forth limitations not disclosed or taught by any of the references Cluff, Laing or Genequand. Such demonstration supports a conclusion that Claim 11 is nonobvious over any combination of the cited prior art by virtue of features required by Claim 11, irrespective of whether or not Claim 8 is nonobvious over the cited prior art.

VII.D.4 Rejection of Claim 12

Claim 12 recites in part (underlining added for emphasis):

> The method of Claim 8, wherein the lens has a light receiving region, further comprising incorporating into the receiving region a multiplicity of receiving subregions that each receive light arriving parallel to the incoming light axis, and that each disperse such received light substantially uniformly over an entire surface of a target conversion device.

As may readily be seen, the features required by Claim 12 are sufficiently similar to those required by Claim 6 that the remarks set forth above in respect of Claim 6 can be considered, *mutatis mutandis*, and seen to support a conclusion that requirements set forth in Claim 12 render the claim nonobvious over all of the cited references irrespective of whether or not Claim 8 from which Claim 12 depends is held nonobvious over the cited prior art.

The Examiner asserts that Genequand discloses a multiplicity of receiving sub regions/slats that each receive light arriving parallel to the incoming light axis, and that each disperse such received light substantially uniformly over an entire surface of a target conversion device/ inner conduit (27). However, as described in detail in remarks set forth in section *VII.D.4 Rejection of Claim 6, and Shadow Tolerance Generally*, The requirement that subunits of the lens distribute light uniformly over an entire target is incompatible with the lens of Genequand, because Genequand describes the various subunits of its lens as having the same, single focus. The remarks set forth in *VII.D.4 Rejection of Claim 6, and Shadow Tolerance Generally* that support the foregoing conclusion are incorporated here by reference rather than being repeated in detail.

None of the references Genequand, Cluff or Laing thus describe all of the features required by Claim 12. Accordingly, Claim 12 is for at least this reason nonobvious over the cited references, even if combined, irrespective of whether or not Claim 8 from which Claim 12 depends is nonobvious over the cited references.

Conclusion

The remarks set forth above describe evidence, persuasive opinion of another USPTO examiner acting in his official capacity, law and arguments that address each and every ground of rejection maintained by the Examiner in respect of the claims of the subject application. The remarks and evidence amply support a conclusion that the outstanding rejections are improper, and reversal of the Examiner as to each rejection is therefore respectfully requested. The Commissioner is requested to construe this Appeal Brief as including a petition to extend the period for submission under 37 CFR 1.136(a) by the number of months necessary to make this submission timely filed.

Respectfully submitted,

9-30-2008
Date: September 30, 2008

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VIII. CLAIMS APPENDIX

1. A solar converter apparatus for converting incoming light to electricity, comprising:

   a) a support structure for floating on a liquid bath, the structure having:

      i) a substantially fixed relationship to an incoming light axis that is parallel to useful incoming light,

      ii) an elevation rotation axis at a fixed azimuth alignment angle from the incoming light axis, the support structure being rotatable about the elevation rotation axis, and

      iii) guidance interface features connecting the support structure to a guidance frame that aligns the elevation rotation axis at the fixed azimuth alignment angle to an azimuth of the source of incoming light, and that provide a rotation reference for the support structure rotation about the elevation rotation axis to align the incoming light axis with the source of incoming light;

   b) at least one photovoltaic conversion device mounted within the support structure and adapted for converting concentrated sunlight into electricity; and

   c) a lens coupled to the support structure for guiding light that is parallel to the incoming light axis and is received over a receiving region toward a conversion device that is mounted within the support structure, the conversion device having an active area that is smaller than an area of the receiving region;

   wherein the liquid bath is a coolant that provides primary cooling of the conversion device through thermal contact with an exterior of the support structure.

2. The apparatus of Claim 1, wherein the photovoltaic mounting is on an inside of an exterior wall that in operation is in contact with the liquid bath at a point directly transverse the wall from a point of the mounting.

3. The apparatus of Claim 1, wherein the support structure is a first support structure, and is disposed in contact with a liquid bath in an array of support structures, substantially abutting adjacent support structures that each have an elevation rotation axis parallel to and in a plane with the elevation rotation axis of the first support structure.

4. The apparatus of Claim 1, wherein light parallel to the incoming light axis that enters with uniform density across an entire surface of the lens exits the lens at angles with respect to the incoming light axis, an

average of all such exiting light angles defining a light delivery axis, the light delivery axis having a significant non-zero angle with respect to the incoming light axis.

5. The apparatus of Claim 1, wherein the receiving region of the lens is subject to shadowing that causes substantially non-uniform illumination of the receiving region of the lens, the apparatus further comprising a shadow toleration mechanism that coordinates light entering through the lens with each target photovoltaic conversion device to avoid substantially non-uniform illumination of operating photovoltaic conversion devices due to such shadowing.

6. The apparatus of Claim 1, further comprising a plurality of subregions of the lens that each receive light substantially parallel to the incoming light axis over a corresponding receiving subregion, wherein each subregion is configured to disperse the received light substantially uniformly over an entire surface of at least one corresponding target photovoltaic conversion device.

7. The apparatus of Claim 1, wherein during operation the incoming light axis is aligned with a light source elevation angle, and the support structure floats in a coolant bath that has an average surface plane, the apparatus further comprising a device mounting site within the support structure, upon which a photovoltaic converter device is mounted, which during operation is below the coolant bath average surface plane for all light source elevation angles within 45 degrees from vertical.

8. A method of collecting incoming light for conversion to electricity, comprising:

a) mounting a conversion device at a mounting site within a support structure having an elevation rotation axis;

b) coupling a lens to the support structure to concentrate and guide incident light arriving parallel to an incoming light axis toward the conversion device;

c) floating the support structure on a liquid bath;

d) aligning the support structure so that the elevation rotation axis is at an azimuth alignment angle with respect to a source of light energy;

e) rotating the support structure about the elevation rotation axis to align the incoming light axis toward the source of light energy; and

(f) cooling the conversion device primarily through thermal contact between the liquid bath and an exterior of the support structure.

9. The method of Claim 8, further comprising cooling the conversion device primarily through thermal contact between the liquid bath and an exterior of a wall of the support structure, the wall having an interior

upon which the conversion device is mounted opposite an expected area of contact with the liquid bath, such that in operation at least one line perpendicular to the wall traverses the conversion device mounting on an immediate inside of the wall and the liquid bath on an immediate outside of the wall.

10. The method of Claim 8, wherein the support structure, lens and conversion device are part of a first collection pontoon, further comprising substantially abutting the first collection pontoon in an array with adjacent collection pontoons that each have an elevation rotation axis parallel to and in a plane with the elevation rotation axis of the support structure of the first collection pontoon.

11. The method of Claim 8, wherein a light delivery axis is defined as a line that intersects the incoming light axis at a center of the lens and has an angle with respect to the incoming light axis that is equal to an average angle of light exiting the lens when such light entered the lens parallel to the incoming light axis and uniformly distributed over an entire surface of the lens, the method further comprising configuring the lens to have the light delivery axis at a significantly non-zero angle with respect to the incoming light axis.

12. The method of Claim 8, wherein the lens has a light receiving region, further comprising incorporating into the receiving region a multiplicity of receiving subregions that each receive light arriving parallel to the incoming light axis, and that each disperse such received light substantially uniformly over an entire surface of a target conversion device.

13. The method of Claim 8 wherein the liquid bath is a coolant bath having an average surface plane, the method further comprising positioning the conversion device mounting site below the coolant bath average surface plane for all light source elevation angles within 45 degrees from vertical.

14. The method of Claim 8, further comprising incorporating a light source direction sensor within each pontoon.

IX. EVIDENCE APPENDIX

The following references relied upon by the Appellants were entered into the record at least when considered by the Examiner on the dates indicated. A copy of each reference is attached.

The following paper was submitted by the Appellant to the Examiner on the date indicated, but appears in the PAIR Image File Wrapper as an "NPL" document not available for download, and therefore it may not be accessible to the panel for consideration:

1. ***Interview Summary and Supplemental Cluff Analysis*, 6 pages:** **04/09/2008**

Each of the following references was cited in an Information Disclosure Statement mailed February 27, 2008 and was considered by the Examiner March 20, 2008:

2. Pub. WO 03/032404 of PCT US02/32550 (Morgal) w/ Intl Search Report 04/17/2003
3. WRITTEN OPINION Re: PCT US02/32550 (Morgal), 4 pages, 08/22/2003
4. REPLY TO WRITTEN OPINION Re: PCT US02/32550 (Morgal), 8 pages, 10/22/2003
5. INTERNATIONAL PRELIMINARY EXAMINATION REPORT Re: PCT US02/32550 (Morgal), 3 pages including cover, 11/13/2003,

Each of the following references was cited in an Information Disclosure Statement mailed to the U.S. Patent Office on **January 11, 2005** and considered by the Examiner on April 23, 2007:

6. U.S. Patent No. 4,771,764 issued 9/20/1988 to Cluff.
7. U.S. Patent No. 5,445,177, issued 8/29/1995 to Laing, et al.
8. U.S. Patent No. 4,238,246, issued 12/9/1980 to Genequand, et al.
9. *Webster's Encyclopedic Unabridged Dictionary of the English Language*, © 1989 dilithium Press, Ltd., p. 1480

X. RELATED PROCEEDINGS APPENDIX

None.

XI. TABLE OF CASES

In re Umbarger, 407 F.2d 425, 430-31, 160 USPQ 734, 738 (CCPA 1959)

In re Ratti, 270 F.2d 810, 123 USPQ 349 (CCPA 1959)

In re Gordon, 733 F.2d 900, 221 USPQ 1125 (Fed. Cir. 1984)

KSR v. Teleflex, 127 S. Ct. 1727; 167 L. Ed. 2d 705; 82 U.S.P.Q.2D 1385 (S.Ct. 2007)

Evidence Appdx 1

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	**Richard Morgal**	Confirmation No.: **1563**
Serial No.:	**10/821,593**	Group Art Unit: **1795**
Filed:	**April 9, 2004**	Examiner: **Hall, Asha J.**

For: **METHOD AND APPARATUS FOR SOLAR ENERGY COLLECTION**

USPTO: Asha Hall Facsimile 571-273-9812
Commissioner for Patents
P.O. Box 1450
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INTERVIEW SUMMARY and SUPPLEMENTAL CLUFF ANALYSIS

A telephonic interview between the undersigned, Examiner Hall and SPE Neckel was held on Monday, April 7, 2008, beginning at 3:00 PM EDT. This paper summarizes the interview, and provides supplemental analysis of the cooling taught by the Cluff reference as requested by the Examiner.

The interview primarily revolved around the issue of cooling. Sections of Cluff that address cooling were discussed, as well as the manner in which the Applicant physically cools photovoltaics as shown in Applicant's Figures 4 and 5. Cluff Figures 1, 13, 15 and 17 were discussed, together with some of the text describing those figures. Text of the Laing reference that rejects two-axis tracking was also discussed, in particular the Abstract and the Prior Art section in column 1 of Laing.

Agreement was not reached, but the Examiner requested that the analysis of the cooling taught by Cluff be set forth for the record, as contrasted with the invention as claimed by the Applicant. Such analysis is described in the remarks set forth below in even greater detail than was covered in the interview.

In regard to cooling, the Applicant's independent Claim 1 requires in part (underlining added for emphasis): "wherein the liquid bath is a coolant that provides <u>primary cooling</u> of the conversion device through thermal contact with an <u>exterior of the support structure</u>." Similarly, independent Claim 8 requires in part (underlining added for emphasis): "(f) <u>cooling</u> the conversion device <u>primarily</u> through thermal contact between the <u>liquid bath and an exterior of the support structure</u>." Achieving such cooling while permitting the support structures to rotate, as is necessary for two-axis tracking required ingenuity and insight. The Applicant solved the problem by using features as shown in Figures 4-6 of the application as filed. Heat from the photovoltaic 100 is conducted via element 96 to the surrounding pond. The shape of the protrusion, as well as the asymmetrical nature of the focusing lens, is a good solution of the problem of keeping adequate thermal

contact between the photovoltaic devices and the pond, while also permitting close packing of the pontoons (see ¶ 70 p. 5-6 of the published application, and ¶ 71-72, or ¶ 63-65 p. 14 of the application as filed).

Ponds and Cooling in Cluff

The remarks set forth below endeavor to address each and every aspect of Cluff that either describes cooling conversion devices (photovoltaics, in Cluff), or appears potentially suggestive of the elements of Claims 1 or 8 that are set forth above. The distinctions of the claimed elements over Cluff's teaching are noted.

Use of Ponds in Cluff

Cluff teaches only a single function for the pond that relates directly to the solar energy collectors: to provide physical support for solar collection panels, either directly or via an intermediate raft.

Figure 1 of Cluff shows solar collectors supported by a pond. In particular, Cluff states (col. 1 lines 35-38, underlining added for emphasis): "[A] solar energy collection and conversion apparatus or system 30 utilizing an array 31 of absorbers supported on a rotating or arcuately movable floating platform 32." The subsequent text of Cluff (to col. 4 line 16) elaborates upon the pond (which may be any body of water) and the platform. The platform 32 in turn supports solar collection panels that are broadly comparable to the support structure required in Claims 1 and 8, aside from cooling. **Figures 20 and 21** illustrate another example of collectors mounted on an intermediate floating raft (98 of Figure 21; col. 7 lines 44-53). These embodiments cannot cool the photovoltaics as required because the exterior is not in contact with the pond.

However, Cluff also describes supporting solar collectors directly in the pond without an intermediate support platform, as illustrated in **figures 13, 14, 17 and 18**. Details of the "pontoons" employed in these figures are illustrated in figures 15, 16, 22 and 23, which are described in remarks set forth further below in a subsection entitled "Cooling Techniques in Cluff."

No mention is made of cooling in the description of **Figures 13 and 14** (col. 6 lines 40-47). **Figure 17** illustrates a collector for heating water with solar energy, rather than using photovoltaics. The tube in the center collects the heated water. The three tubes 83, 84 and 85 are secured to the periphery 86 of the trough (pontoon) 80, and are controllably filled to varying degrees to control the rotational angle of the trough 80 (col. 7 lines 10-23). The collectors of Figure 18 are described as floating on the pond within an azimuth-adjusting frame 63, which is described with respect to Figures 13 and 14; there is no mention of cooling.

Using the pond for cooling. Interestingly, Cluff does describe using the pond for cooling. As will be seen, such cooling is clearly intended to be for nearby buildings. The pond is not suggested for cooling photovoltaics, and in fact the suggested use would interfere with cooling photovoltaics.

In this regard, Cluff states (col. 5 lines 47-54, underlining added for emphasis): "The reservoir on which the collector floats could be used as a storage of hot water for heating in the winter or cold water for cooling in the summer. The system would be connected to the building, apartments or individual homes through insulated pipelines."

In considering this description by Cluff, it is observed that photovoltaics would never require heating; as such, the construction of the sentence, which suggests both heating and cooling purposes, immediately suggests that photovoltaics are not the intended targets of such heating/cooling.

That the system "would be connected to the building" clearly shows that the building is at least an intended target for the cooling in the summer. However, that implies that waste heat would be transferred to the pond from the building; this would reduce the effectiveness of the pond if it were intended to serve for cooling the photovoltaics. Thus, cooling/heating is clearly described for building(s) but is not described for photovoltaics; and dual use would impair the effectiveness. If cooling the photovoltaics had been considered, Cluff would have at least noted the conflict inherent in attempting to use the same source to cool both buildings and photovoltaics.

Thus the description contains no suggestion to use the pond for cooling the photovoltaics, and in fact seems to suggest to the contrary. In any event, the issue is not particularly relevant, because the requirement of Claims 1 and 8 is that the cooling be primarily done by the pond liquid contacting an exterior of the support structure. That is not what Cluff does, as will be seen in the remarks below, regardless of the source/destination of the liquid in the cooling pipes.

Cooling Techniques in Cluff

Direct teaching. Cluff expressly addresses cooling photovoltaics (col. 5 c. lines 30-45), stating in part (underlining added for emphasis): "A liquid can pass through cooling tubes mounted adjacent the surface on which the photovoltaic cells are mounted, well known in the art, at a rate high enough as needed to keep the temperatures of the cells below a specified amount." The fact that the liquid is described as "passing through ... at a rate high enough ..." shows that Cluff is describing forced liquid cooling, as in an automobile engine, for example. This is far different than cooling by thermal contact between the liquid of the supporting pond and the exterior of the supporting structures (pontoons), as required in Claims 1 and 8.

Cluff makes no different suggestion about cooling the photovoltaics, although a somewhat different embodiment is illustrated in **Figures 22-23**. To the contrary, an examination of details of each of the "pontoons" that Cluff describes as supported directly on and in the pond shows that they were physically incapable of cooling as required by the Applicant's Claims 1 and 8.

Cluff illustrates one method of cooling photovoltaics in **Figures 10-11**. **Figure 10** on drawing sheet 2 is more clear in this regard, but both illustrate how cooling pipes 53 may be embedded within a material 52 on which the photovoltaics 51 are supported, such that the cooling pipes 53 are immediately below (and thus adjacent to) the photovoltaics 51. **Figure 11** shows an arrangement of the cooling pipes 53 (within the support material 52). **Figure 12** shows an alternative method of forming the coolant pipes within the support material 52. **Figure 9** shows the coolant pipes connected from the support material 52 to some other place by means of flexible couplings ("P"). (See col. 6 lines 21-39.)

In all instances illustrated in Figures 9, 10, 11 and 12, the material 52 that supports the photovoltaics 51 is illustrated as being quite thick. It is clearly the intention that the excess heat will be conducted away via the coolant in the cooling pipes 53, rather than through the (thick) support surface 52 to an exterior of such support surface. Thus, the cooling illustrated in Figures 9-12 is primarily through contact between a liquid (from somewhere) and *an interior of cooling pipes 53*. This is entirely unlike the cooling required by Claims 1 and 8 ("primarily through thermal contact between the liquid bath and an exterior of the support structure").

Source of cooling liquid: In response to a question posed by the Examiner during the interview, please note that Cluff contains no suggestion that the liquid for cooling pipes 53 (or 107) should come from the support pond. Cluff does not appear to have had any inkling of such a concept, so of course makes no direct negative statement about it. However, the following suggestion in Cluff implies that the photovoltaics should not be cooled by the pond liquid: Cluff suggests that the energy in the cooling liquid should be "collected and put to useful work" (col. 5 lines 42-46). Conveying such energy to the support pond would complicate and interfere with doing "useful work." Thus, the suggestion that the energy should be collected for useful work implies that the cooling liquid would go somewhere other than the pond ... perhaps to some sort of heat exchanger, for example.

Thus the description contains no suggestion to use the pond for cooling the photovoltaics, and in fact seems to suggest to the contrary. In any event the issue is not particularly relevant, because the requirement of Claims 1 and 8 is that the cooling be primarily done by the pond liquid contacting an exterior of the support structure. That is not what Cluff does in Figures 9-12, regardless of the source/destination of the liquid in the cooling pipes.

Implicit teaching. The structure of the "pontoons" that Cluff describes as directly contacting the pond is such that it is not practical to cool the photovoltaics by thermal contact between the pond and an exterior of the support structure.

Figure 15 shows details of panels 65 that house photovoltaics and are intended for direct contact with the pond. Cluff suggests that the panels 65 (*i.e.*, the pontoons or support structure; col. 6 lines 64-66,

underlining added for emphasis) "may comprise hollow elongated U-shaped trough 69 having a lens 70 covering the open space between legs 71 of the trough for receiving the solar rays 72 and a bank of photovoltaic cells 73 mounted on the bight 74 of the U-shaped configuration ..." No reason is set forth for choosing such a shape. During the interview, the undersigned suggested that perhaps the hollow might be used to conduct the forced liquid, but on reflection this seems unlikely as it is very dissimilar from the pipes described elsewhere (too wide and open). It seems more likely that it is simply intended to ensure that the pontoons do not leak, and thus remain floating.

The hollow shape of panels 65 does allow one to draw a fairly firm conclusion that no consideration was given to cooling the photovoltaics through thermal contact between the pond and an exterior of the support structure. As is well known, air is a very poor conductor of heat. As such, placing a hollow directly beneath the mounting points of the photovoltaic devices would make extracting the excess heat very difficult. Extracting the heat as required by Claims 1 and 8 (through thermal contact with an exterior of the support structure) would be made particularly difficult by the described hollow.

The collectors 87 of Figures 18 and 19 may also be supported directly in contact with the pond, and may house photovoltaic converters. Cluff states (col. 7 lines 39-43, underlining added for emphasis): "FIG. 19 further illustrates that the collector 87 may comprise a hollow trough 93 covered by a glass or lens 94 for directing solar rays 72 through the lens onto photovoltaic cells 43 to be positioned on the bottom 95 of trough 93 in the usual manner." No detail of the photovoltaic mounting is provided, nor is a cooling technique shown or described. However, the fact that the trough is hollow implies that it would not efficiently conduct heat to the outside of the trough. The thickness of the dimension between the bottom 95 of the trough and the outside of the part 89 also suggests that heat would not transfer effectively. Were the material solid metal, perhaps heat would transfer sufficiently, but unfortunately the troughs would sink! Looking at Figure 19, it is surmised that the unreferenced dotted line is meant to represent the water level; if so, the water level would not be high enough to cool much of the photovoltaics, even if heat transfer through the trough body was practical.

Thus, the photovoltaic support structures ("pontoons") of Cluff that directly contact the pond liquid appear inimical to cooling the photovoltaics in the manner required by the Applicant's Claims 1 or 8. Moreover, there is no positive suggestion whatsoever in Cluff in regard to cooling the photovoltaics by means of the pond liquid at all, and certainly not by contact with an exterior of the support structure, as required.

Other photovoltaic cooling: The structures of **Figures 16 and 22-24** may also support photovoltaics, and may float in the support pond. However, the photovoltaics are mounted in a place that completely precludes cooling via thermal contact with the outside of the structure. **Figures 22 and 23** show cooling tubes

107 mounted adjacent to photovoltaics 51, which is substantially the same as Cluff teaches with reference to **Figures 9-12** for cooling photovoltaics. Cluff makes no other suggestion in regard to cooling photovoltaics.

Conclusion

The remarks set forth above demonstrate that Cluff makes no suggestion in respect of cooling photovoltaics except for using one sort or another of cooling tubes through which cooling liquid is forced. There is no suggestion that such cooling liquid might even come from the pond. Moreover, there are two different sections of Cluff that imply that the pond would not be used for cooling. Yet further, the structure of the solar collection panels that Cluff describes as floating in the pond is such that the required cooling is impractical. Thus, there is a complete absence of suggestion of the cooling technique required by each of the Applicant's pending independent claims, and a great deal of information that implies that such cooling was neither thought of nor practical.

As argued in two papers faxed to the Examiner on March 27, 2008 and April 7, 2008, achieving effective cooling in the manner required by Claims 1 and 8, while using two-axis tracking as described in Cluff, was a difficult problem. Laing teaches the required cooling, but to do so found it necessary to change the principle of operation to single axis tracking, and forcefully rejected two-axis tracking. Thus, Laing cannot reasonably be construed as demonstrating that it is possible, let alone obvious, to use two-axis tracking while cooling the "pontoons" in the required manner.

As such, the Examiner is respectfully requested to withdraw all pending rejections, and to conclude that the amendment submitted on February 27, 2008 placed the application into condition for allowance. The undersigned will be pleased to promptly address any further issues at the Examiner's request.

Respectfully submitted,

Date: 4/9/2008
(April 9, 2008)

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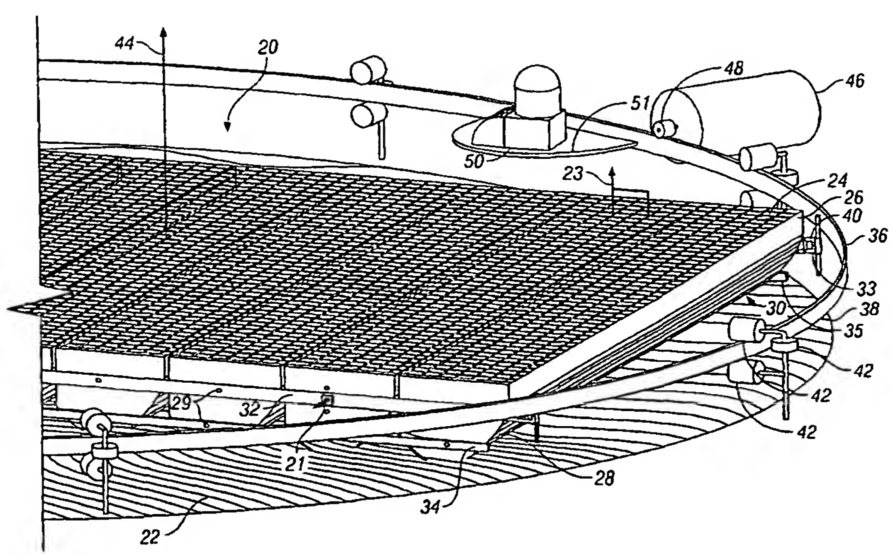
[Continued on next page]

(54) Title: METHOD AND APPARATUS FOR SOLAR ENERGY COLLECTION



(57) Abstract: A pontoon structure (30) is described that may be floated on a body of coolant liquid (38), with others in array (20). The entire array may be aligned with the sun in an azimuth direction, and each pontoon may be rotated to align it with the sun elevation. A solar energy conversion target, typically a photovoltaic conversion device, may be mounted on a portion of the pontoon structure that remains below the coolant over a wide range of sun elevations. An asymmetric focus lens may be used to direct light entering the pontoon toward the conversion target. A lens to make solar conversion systems shadow-tolerant is also described that is useful with pontoons that shadow each other, improving target illumination uniformity in the presence of partial shadowing by directing light uniformly toward the target from each plurality of subregions.

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METHOD AND APPARATUS FOR SOLAR ENERGY COLLECTION

TECHNICAL FIELD.

001 This invention relates to the solar energy field, and more specifically to systems for collecting, concentrating and converting solar energy to a more readily distributed form.

BACKGROUND ART

002 Efficient collection of solar energy entails capturing as much of the incident sunlight striking a given site space, ensuring a minimum amount of land is consumed for energy generation purposes. The high cost of conventional solar collectors and their intolerance to being shadowed has led tracking solar power plant designers to typically distribute solar collectors with a site utilization collection efficiency of less than 50 percent. Two axis-tracking photovoltaic systems typically deliver more energy per solar collector than fixed photovoltaic systems but require more land, with less than 25 percent site utilization collection efficiency being typical.

003 Concentration of the sun's rays can significantly reduce the amount of energy conversion material required to create a given amount of power. Using concentration lenses reduces the expensive energy conversion device's size and relative cost. When solar concentration is utilized, tracking the sun's position in the sky is typically required to deliver the sun's concentrated energy accurately to a smaller target. Single axis tracking systems are known in which the sun is tracked only around the azimuth axis, but in such systems a positional variation of the focal point with various sun heights typically causes significant inefficiencies in solar concentration. On the other hand, the electro-mechanical systems required to accurately track the sun's position and hold the collector in position for two-axis tracking systems have historically consumed gains that might be realized by using concentrated sunlight and smaller energy conversion devices. Thus, there is a need for cost-effective solutions to tracking and concentrating sunlight onto relatively small conversion devices.

004 Converting concentrated sunlight into electricity typically results in substantial waste heat. Therefore, there is need for an efficient thermal management process that provides a reliable method of removing such waste heat from the energy conversion device. Most approaches to solving this problem require an active pumping process and distribution system that involves water moving though tubes and hoses, requiring the system to be failure-free in order to ensure survival of the energy conversion device in the harsh concentrated sunlight. A single failure of the cooling system is likely to irreparably damage the costly energy conversion devices.

SUMMARY OF THE INVENTION

005 The invention is a solar energy collection system that provides a combination of features to improve upon the present state of the art, enhancing efficiency in the use of land for solar collection, and permitting more effective use of high efficiency photovoltaics.

006 One embodiment includes a solar converter apparatus that has a support structure, such as a pontoon, for floating on a liquid bath connected to a guidance frame for azimuth alignment. The embodiment further includes at least one photovoltaic conversion device mounted within the support structure, which is rotatable about an axis for elevation alignment, and a lens for guiding aligned incoming light toward the conversion device, which is smaller than the lens. The conversion device may be mounted on the support structure such that it is below the liquid level across a wide operating elevation rotation range. The lens may bend incoming

light asymmetrically. The converter apparatus may be configured to provide uniform light distribution to operating photovoltaic devices in spite of partial shadowing of the lens.

007 A lens that may be used to provide uniform light distribution to operating photovoltaic devices in spite of partial shadowing includes subregions that each, individually, distribute their light uniformly over a solar energy conversion target.

BRIEF DESCRIPTION OF THE DRAWINGS

008 Fig. 1 is a perspective view of a pontoon solar collector array on a coolant pool.

009 Fig. 2 shows a spacing rod attachment to a perimeter ring for varying liquid levels.

010 Fig. 3 is a perspective view of an end of a pontoon collector with a motor/gearbox rotational actuator and solar optical tracking system components.

011 Fig. 4 is a cross sectional view of adjacent pontoon solar collectors aligned for collection from 90 degrees elevation.

012 Fig. 5 is a cross sectional view of adjacent pontoon solar collectors aligned for collection from 55 degrees elevation.

013 Fig. 6 is a cross sectional view of adjacent pontoon solar collectors aligned for collection from 30 degrees elevation.

014 Fig. 7 is a perspective view of a partially shaded conventional lens and target.

015 Fig. 8 is a perspective view of a partially shaded, offset-tiled Fresnel lens with target.

016 Fig. 9 is a perspective view of a Fresnel lens tiled diagonally to a partial-shade line.

017 Fig. 10 is a perspective view of a target with a single tile from a Fresnel lens

018 Fig. 11 shows a partly shaded, shadow tolerant line focus tiled Fresnel lens.

019 Fig. 12 is a perspective view of an optical solar elevation tracker mounted on a pontoon collector end cap.

020 Fig. 13 is a perspective view of optical solar azimuth tracker apparatus.

021 Fig. 14 shows optical angular ranges of elevation-tracking subsystems.

022 Fig. 15 is a plan view of optical angular ranges of azimuth-tracking subsystems.

023 Figs. 16A and 16B are a functional block diagram of an optical tracker circuit.

024 Fig. 17A and 17B are a flow chart of steps for processing photosensitive linear array data.

025 Fig. 18 schematically illustrates some components that may interface with the optical solar tracker system.

026 Fig. 19 shows the photovoltaic cell divided to provide shadow tolerance.

027 Fig. 20 is a cross sectional view of light transmission through secondary optics to a photovoltaic cell.

028 Fig. 21 shows a subsectioned target and a lens having subregions comprised of discontiguous subsubregions.

029 Fig 22 is a cross sectional view of light paths to a target photovoltaic cell using a secondary reflector.

MODES OF CARRYING OUT THE INVENTION

Introduction

030 The solar collection method and apparatus described herein addresses a number of the needs evident in the prior art, permitting improvements in collection efficiency. The method and apparatus are illustrated by detailed examples in which the collectors are shown as being essentially elongated pontoons, surfaced with concentrating lensing and typically floated in an array on a liquid pond, with the array rotated as a unit to align toward a light source azimuth. Each collection pontoon rotates about it's own axis

for alignment with the light source elevation. The illustrated embodiments encompass only a few of the many forms that the invention, as defined exclusively by the attached claims, may take.

031 The illustrated pontoon solar collector is constructed to float on a cooling pond (typically water) and to track the sun in azimuth and elevation. Compared to earlier systems, they may be spaced more closely to increase land utilization, and also have features to permit high levels of light concentration, which allows using a smaller amount of higher-efficiency solar conversion devices. The principles that permit these enhancements in efficiency may be used with many other types of solar converters to good effect.

032 A roof lens is provided on the upper surface of the pontoon solar collector, and may cover substantially the entire upper surface. The pontoon solar collector roof lens concentrates the incident sunlight toward the conversion device. It may guide the light directly onto the conversion device, or indirectly if the light is further refracted or reflected before reaching the conversion device.

033 The pontoons rotate to track sun elevation, and if close together, as is desirable for efficient land utilization, will shadow each other at some elevations. Shadowing could cause irregular illumination of a target photovoltaic converter, resulting in substantial decrease in conversion efficiency. Solutions are described that ensure that the target is reasonably uniformly illuminated, even when a lens is partially shadowed, thus providing shadow tolerance. In one such solution, the roof lens may utilize a tiled lens design in which each tile is a subregion of the roof lens, and each tile delivers the light that passes through it uniformly over the surface of the target. Accordingly, because each particular tile contributes only a certain small proportion of the light to the target, uneven illumination of the particular tile will cause uneven shading of the target only to the same small proportion. That is, other tiles that are fully, or at least differently shaded, will dominate the light distribution to the target. Many ways to effect shadow tolerance with lenses are described below, as well as other techniques for providing shadow tolerance. Such shadow tolerance allows the pontoon solar collectors to be placed closely, substantially abutting, without causing uneven target illumination that would substantially impair conversion efficiency. Thus, shadow tolerance facilitates efficient sunlight collection over substantially all of the land area covered by the pontoon array.

034 The conversion device, typically a photovoltaic cell, is not 100% efficient in converting incoming light to an intended form for transportation to an end user, and a significant portion of the energy is typically converted to heat that raises the temperature of the photovoltaic cell. Particularly for conversion devices that operate best with highly concentrated sunlight but at low temperatures, heat removal is needed for maximum efficiency, or even for survival of the conversion device.

035 Active cooling may be used in some embodiments, but passive cooling may eliminate some complexities, and reduce the likelihood of catastrophic failures due to failure of active cooling systems. Mounting the conversion devices in close thermal contact with the cooling liquid bath may facilitate passive cooling. Effective passive cooling may be obtained by mounting the conversion devices on a portion of the pontoon that is actually submerged in the cooling liquid bath, even as the pontoon is rotated over a wide range of elevation angles.

036 In order to keep the conversion device mounting closely thermally coupled to the cooling bath, for example mounted on a region that remains submerged below the coolant level, the lens may be designed with an asymmetric focus. Light that enters a lens along an incoming light axis will exit the lens at an exit angle from the incoming light axis. For most lenses, the exit angle, averaged for uniform light over the lens surface, will not deviate much from the incoming light axis. For an asymmetric focus lens, however, the

average exit angle is substantially different than the incoming light angle. By using an asymmetric focus lens, the geometry of the pontoon can be optimized to permit the conversion device mounting sites to be positioned better ... for example, the sites may remain below the coolant surface level over the entire elevation operating range of the pontoon.

037 A tracking system is used to ensure that the concentrated sunlight hits the targeted energy conversion device. In one of many solutions for tracking, an optical solar tracking system may be directly attached to the pontoon solar collector, providing immediate optical feedback of orientation changes made by the tracking system's actuators. It will typically be convenient to have an azimuth drive system that is external to the individual pontoons to align a pontoon, or an array of pontoons, to the correct orientation with respect the sun's azimuth. However, a drive system to rotate the pontoon(s) to achieve elevation alignment may be located primarily on each individual pontoon, or may be located externally and coupled so as to align a number of pontoons (such as all of the pontoons in an array). Whether the drive impeller is on the pontoon or not, the angle sensors may be either on or off the pontoon, with advantages accruing to both methods.

038 The weight of the floating pontoons is carried by the pond liquid, typically water with a coating of oil to reduce evaporation, which allows for supported tracking in both azimuth and elevation, reducing the mechanical requirements of the tracking actuation system. Additionally, the low profile of floating pontoons positioned immediately adjacent to one another provides minimal wind loading, further reducing the mechanical requirements of the tracking actuation system.

039 Employing combinations of the features described herein may permit reduction in costly photovoltaic cell surface area, a significant reduction in mechanical tracking infrastructure, and/or a significant reduction in plant site area. Thus, combinations of these features should substantially reduce the cost of solar power plant implementation.

Pontoon Solar Collectors on Water and Azimuth Tracking Motion

040 Referring to Fig. 1, pontoon solar collector array 20 floats on a pond surface 22. Each pontoon solar collector 30 has a light refracting roof lens 24 that is attached to the top of the pontoon body 26 and to two end caps 28, one on each end of the body 26. Both end caps 28 and roof lens 24 are typically sealed to the body 26 to prevent water from seeping inside the pontoon solar collector 30. Each end cap 28 provides attachment points 29 to a spacing rod 32 or 33 and, at least in embodiments in which rotational control is shared between different pontoons, to a control rod 34 or 35, to permit or provide rotation about a rotation axis defined between the spacing rod attachment points.

041 Both ends of each spacing rod 32, 33 are typically connected to a perimeter ring 36 that encircles the pond 38. The attachment between the perimeter ring 36 and spacing rods 32, 33 may be a vertically sliding, mechanical fastener 40, allowing the water level 22 of the pond 38 to vary within limits and still enable the pontoon solar collector array 20 to track the sun. The perimeter ring 36 may be held in position by wheels and/or pulleys 42 in a manner that would allow the perimeter ring 36 to rotate freely around its center vertical axis 44.

042 Rotation around the center axis 44 of the perimeter ring 36 may be effected by any appropriate means, such as a fixed azimuth actuation motor 46, connected to the perimeter ring 36 through a drive wheel or gear 48, so long as azimuth positional adjustment is provided to track the sun. Tracking both azimuth and elevation permits alignment of an incoming light axis of each pontoon with the sun as it moves throughout each day and season. The pontoon solar collector array 20 is correctly tracking the

azimuth of the sun when the rotational axes of the pontoon collectors 21 are perpendicular to the sun's azimuth. (Note that in other embodiments, the angle between the pontoon collector's rotational axis and the incoming light axis -- the sun -- need not be 90 degrees if the optical path is adjusted to correspond to such a non-perpendicular angle between rotational axes and sun azimuth.)

043 An optical solar azimuth tracking system 50 may be attached to the perimeter ring 36 to locate the sun's azimuth position in the sky relative to the pontoon solar collector array 20. The tracking system may provide electrical control signals to a fixed azimuth actuation motor 46, which in response moves the perimeter ring 36 and pontoon solar collector array 20 to track the sun azimuth. Electrical wiring, carrying the power generated within the pontoon solar collectors 30, and sometimes carrying control signals, may be routed to the center axis region of the perimeter ring 36 via the spacing rods 32, 33 and directed downward to the bottom of the pond, below the operational region of the pontoon solar collector array 20. Once below the array 20, the cables may be directed to an edge of the pond 38, and brought above the surface for access to the grid and control of the azimuth actuation motor 46.

044 In an alternative embodiment, a perimeter ring may be directly attached to spacing rods, which are connected to the end caps of each pontoon solar collector in an array. The perimeter ring and spacing rods may be held above the water's surface by the buoyant force of the pontoon solar collector array. A floating azimuth actuator's output shaft, connected to a sprocket, may be engaged with a chain that encircles the perimeter ring. The perimeter ring may be given a "C" profile to hold the chain captive within the perimeter ring. Cylindrical wheels may be used to keep the perimeter ring in position. Such a configuration may be implemented to cover large water bodies with floating azimuth actuation motors and cylindrical positioning wheels, being held in position by tensioned cables running in a grid-like pattern anchored to the shore. Unwanted wave activity from larger bodies of water may be subdued with appropriate wave suppression barriers. A pontoon-supported perimeter ring, or equivalent, may even operate without a firm connection to ground, adjusting azimuth by means of "paddling" as necessary, so that collectors can be almost entirely unmoored (except for connection to an output energy product storage device).

System for Wind and Wave Immunity

045 Fig. 2 shows one method of attaching the ends of the spacing rod 32 to the perimeter ring 36 using a mechanical fastener 40, providing stability to the pontoon solar collector array during windy or wavy conditions and allowing for a water level variation in the pond. The end of the spacing rod 32 may wrap around a notched slider bar 60, which is attached to the perimeter ring 36. An electromechanical solenoid 62 contains a pin 64 that is spring loaded by a spring 66 to force the pin 64 into a notch 68 in the notched slider bar 60. When the electromechanical solenoid 62 is activated, it overpowers the spring 66 and pulls the pin 64 out of the notch 68 in the notched slider bar 60. The end of the spacing rod 32 can now move up or down along the notched slider bar 60, allowing the spacing rod 32 to find its natural floatation level on the variable water level of the pond.

046 Once a floating equilibrium level is attained, the electromechanical solenoid 62 may be deactivated, enabling the spring 66 to force the pin 64 into a notched location, locking the spacer rod 32 to the slider bar 60. By mechanically attaching the perimeter ring 36 to the spacing rods 32, the stability of the entire tracking system can be used to stabilize each pontoon solar collector array from wind and wave action. The pontoon solar collector array may also adjust its floatation level when the weather is calm, or whenever a dramatic water level change occurs within the pond. Daily changes due to evaporation will typically be small enough that the adjustment need not be performed more than once per day. Water loss due to evaporation may be reduced by adding a small

amount of oil to the pond, or by other barriers, such as small buoyant balls (or other self-distributing barrier sections) that cover much, or all, of the pond surface.

Elevation Motion and Thermal Management

047 Fig. 3 shows the end of a pontoon solar collector 30. Attached to the inside face of the end cap 28 by two screws 80 is the case of a motor/gear box 82 having an output shaft 84 protruding through the end cap 28 and through a hole in the spacing rod 32. A block 86 is mounted to the spacing rod 32, with a hole positioned to accept the motor/gear box output shaft 84. A smaller hole in the block 86 enables a pin 88 to be inserted into the block 86 and also through a hole in the motor/gearbox output shaft 84, fixing the motor/gearbox output shaft 84 to the block 86, and to spacing rod 32. The gearbox function contained within the motor/gearbox 82 is used to reduce the speed of the electric motor's output, and may also provide a mechanical brake function to hold the pontoon solar collector 30 in position when there is no power applied to the motor.

048 A small relief 92 in the refraction pattern of the roof lens 24 may be provided to allow light to pass into an area of an optical solar elevation tracking system 90 without refraction. Power for the optical solar elevation tracking system 90, and motor/gearbox 82, may be provided from the power generated by the photovoltaic cells within the pontoon solar collector 30, or by a potential between the electrical connectors 94, passing through the end cap 28, or in any other appropriate manner. The lowest surface of the pontoon solar collector 30 provides a mounting surface for the photovoltaic cells, and may serve as a heat exchange element 96 between the photovoltaic cell and the large thermal mass of the pond.

049 When the pontoon solar collector 30 is azimuth-aligned with the sun, the pontoon solar collectors are rotated as necessary about their rotation axes (generally parallel to a longitudinal axis of the pontoon) to track the sun in elevation. Correct tracking is established when the incoming light axis for which the roof lenses 24 are designed, which is typically but not necessarily a normal vector 23 of a roof lens, is aligned to the sun elevation for each pontoon.

050 The motor/gearbox(s) 82 may be controlled by the optical solar elevation tracking system 90, which is shown mechanically attached to an end cap 28 inside the pontoon collector and electrically wired to the motor gearboxes 82. The optical solar elevation tracking system 90 may be used to determine sun elevation and create an electrical drive signal when alignment error is sensed. In one embodiment, proportional control signals are sent to the motor/gearbox. The output shaft of the motor/gearbox 82 is held stationary to the spacing rod 32 by the pin 88 in the block 86, so that when energized the motor/gearbox case 82 rotates around its stationary output shaft 84. The pontoon solar collector 30 is firmly coupled to the motor/gearbox case 82 and thus also rotates, changing elevation angle.

051 Pontoon solar collectors may also contain two motors, with one motor/gearbox mounted to each end cap and with their output shafts attached to their corresponding spacing rods. Motor/gearboxes contained in the same pontoon solar collector may be wired in parallel, enabling them to work together to keep the pontoon collector's elevation motion uniform and also providing equal weight on each side of the pontoon, keeping the array level on the surface of the pond. (Alternatively, motor/gearboxes and elevation tracking sensors may be placed in alternating ends of adjacent pontoon collectors.) The rotational movement caused by activating the motor/gearbox pair, described above, may also be mechanically translated to other pontoon collectors in the array, via control rods attached to each end cap, so that one motor/gearbox may cause, or assist with, rotation of several pontoons.

052 Conversion of concentrated sunlight into electricity requires management of solar energy that is absorbed by the cell, but is not converted to a form such as electricity that is readily transmitted away. The small thermal mass of the photovoltaic cell will rapidly rise in temperature when subjected to intense concentrated solar radiation unless the heat is removed. Bonding the photovoltaic cell to an intermediate heat transfer material using a thermally conductive adhesive is a conventional method of removing unwanted heat from photovoltaic cells. Once the heat is transferred to the intermediate heat transfer material, a coolant is typically circulated to remove the heat from the intermediate heat transfer material. The photovoltaic cell heat exchange element 96 should have heat-conductive properties that enable it to absorb heat from the illuminated photovoltaic cell through a thermally conductive adhesive and pass the heat readily into the large thermal sink, such as the pond. In some embodiments, natural convection moves the coolant liquid in the pond and provides cooler coolant to the pontoon outside from the cell attachment. Such natural convection helps refresh the coolant contacting the thermal heat sink without a need for pumps, fittings or hoses, delivering a low cost, reliable method of cooling the cells. Active approaches may be used in some embodiments, such as active stirring of the pond liquid, to enhance cooling.

053 In one alternative embodiment, each pontoon collector 30 may contain its own optical solar elevation tracking system 90 and motor/gearboxes 82, eliminating the need for control rods 34. Without using control rods, it is also possible to actuate the elevation movement of each pontoon solar collector using a single optical solar elevation tracking system and a single motor/gearbox. A counter weight may be attached to the end cap, opposite the motor/gearbox assembly, to balance the weight across the pontoon solar collector.

054 Another embodiment may include one motor/gearbox in each pontoon without a counter weight attached to the opposite end cap of the pontoon. The endcap that holds such motor/gearboxes may be alternated for adjacent pontoons in order to balance weights. The spacing rod may be used to distribute the weight of alternating end caps (with and without motor/gearboxes) over the entire array. This approach requires few or no counter weights, and only one motor/gearboxes per pontoon, in exchange for having two versions of the pontoon collector. One version of the pontoon solar collector would have its east end cap holding the motor/gearbox, the other pontoon solar collector version would have its west end cap holding the motor/gearbox.

055 Disposing the elevation rotational axis 102 of the pontoon solar collector 30 away from the center of gravity or force may create a biasing torque load on the motor/gear box to reduce or avoid gear backlash.

056 The braking function of the gearbox can also be performed by other means, such as a spring loaded/electrically deactivated brake or some other means that may hold the pontoon's position in place without consuming electrical power. Arrays with large numbers of pontoon solar collectors may require more that one motor/gearbox pair to actuate the pontoons. Additional mechanical drive capacity, such as for large pontoon solar collector arrays that distribute rotational motion to the motorized pontoons by means of control rods, may be attained by mounting multiple motor/gearbox pairs into multiple pontoons collectors. All motors may be electrically wired in parallel to perform the task of elevation rotation actuation.

057 The each pontoon solar collector may have a single piece body 26 (preferably extrudable), or it may be comprised of a plurality of pieces. In the latter case, a simpler and smaller u-shaped base (typically easily extruded) may be used as an assembly enclosure for the fragile photovoltaic cells and the wiring required for photovoltaic cell interconnect. Such a base may be used to allow the cells to be mounted and wiring assembled in one facility, then shipped as a subassembly to a final assembly site at which sides,

end caps, and roof lens of the pontoon solar collector may be adhered to the body base at a location near the application site, reducing the bulk and cost of shipping fully assembled pontoon solar collectors to the field. Most pieces of the pontoon can readily be designed to be extrudable.

Basic Pontoon Operation

058 In Fig.4, rays from directly overhead are refracted when passing through the roof lens 24 of the pontoon solar collectors 30 and are concentrated at target photovoltaic cells 100 for electric generation. Positioning the cell 100 far away from the roof lens 24 reduces optical light losses associated with extreme light bending near edges of the roof lens 24. Additionally, disposing cell 100 as far as possible from the roof lens 24 minimizes cosine losses associated with light striking the photovoltaic cell at a significant angle.

059 The shape of the pontoon body 26 pontoon solar collectors 30 to be closely packed, essentially abutting, without interfering with one another during elevation tracking rotation. Closer packing permits a higher percentage of actual collection area to derive more benefit from the tracking hardware and the surface area of the pond. Close packing is facilitated by the shapes of the sides of the pontoon body 26, coming straight down or slightly tapering inward toward the target photovoltaic cell 100. With pontoons abutting, almost all of the light incident on the array area traverses a roof lens to be guided to a solar conversion target (with the exception, in some embodiments, of pontoon wall thickness). The pontoon body profile shown gives a large cross sectional area for the pontoon solar collector 30, resulting in a pontoon solar collector with correspondingly large volume and resultant floatation, keeping the lower portion of the roof lenses 24 above the pond's surface 22 even at low sun elevations. Alternative pontoon body profiles may be used to provide different floating dynamics or low sun height operational ranges.

060 As shown in Fig. 5, the pontoon solar collectors 30, 106 are rotated to capture the rays of sunlight coming from 55 degrees elevation above the horizon. The pontoon solar collectors 30, 106 are effectively receiving all the light from the sun with the roof lenses 24, 25 that deliver the light to the photovoltaic cells 100. A portion 104 of the roof lens 25 is shaded by the neighboring pontoon 106. The roof lenses 24, 25 may be designed to distribute the light passing through the partially shaded roof lens 25 uniformly over the surface of the photovoltaic cell 100, typically concentrated by the ratio of the receiving area of the roof lens to the target area of the cell 100. Such design, further described below, reduces or eliminates the performance degradation usually associated with photovoltaic solar collector partial shading, which occurs when tracking solar collectors in an array are placed immediately adjacent to one another. The roof lens design is one way of providing shadow-tolerance to a pontoon solar collector 30. Shadow-tolerance allows pontoon solar collector 30 to be placed immediately adjacent to neighboring collector 106 without experiencing significant shadow-induced conversion inefficiencies, reducing site space requirements to generate a given amount of power.

061 Referring to Fig. 6, the pontoon solar collectors 30, 106 are shown rotated to capture the rays of sunlight coming from 30 degrees above the horizon. One half of the roof lens 24 surface area 105 is effectively blocked by the neighboring pontoon solar collector 106, yet all the incident light is being directed to a targeted photovoltaic cell 100. The offset tile Fresnel lens design of the roof lens 24 enables the sunlight that passes through the partially illuminated roof lens 24 to be evenly distributed on the surface of the targeted photovoltaic cell 100 ensuring efficient conversion of the concentrated light into energy.

062 Heat derived from the concentrated sunlight could quickly damage the photovoltaic cell 100 or significantly reduce is efficiency if not managed properly. The photovoltaic cell 100 is attached to a thermally conductive heat exchange element 96 of the pontoon solar collector 30 in a method that enables the heat absorbed by the cell 100 to be transferred into the heat exchange element 96 of the pontoon solar collector 30, where the heat can then dissipate into the surrounding pond water 22. The narrow protrusion region where the photovoltaic cell 100 is mounted provides enough space for heat exchange element 96, while providing an unobstructed path for the concentrated sunlight to pass to the cell 100 from all parts of the roof lens. The protruding portion of the pontoon solar collector cross section also helps keep the heat exchange element 96 well below the surface of the pond 22 when the pontoon solar collector is tracking the sun at low elevations, assuring that convective thermal currents of the pond's coolant are not interrupted by the photovoltaic cell's heat exchange element 96 being too close to the pond's surface.

063 Note that the pond will not always be perfectly flat, and the "level" of the pond, with respect to the cell 100 or mounting/heat exchange element 96, may be defined as the average level. The cell 100, and/or thermal mounting heat exchange element 96, is "below" the level of the pond over a sun elevation range from 90 degrees, as shown in Fig. 4, down to an angle of less than 30 degrees elevation (or, more than 60 degrees from vertical), as shown in Fig. 6, since the pond level 22 indicates an average pond level.

064 The focal point/line position of the roof lenses 24 may be made asymmetric to facilitate locating the photovoltaic cell 100 on a mounting region that remains in thermal contact with the pond cooling water 22 during low sun heights. "Asymmetric" focus is used to mean that the average exit angle of light that uniformly enters the lens face parallel to the incoming light axis (for which it is designed), as compared to the incoming light angle, is significantly non-zero. As shown (Fig. 4), the asymmetry angle between the incoming and average exiting angles is approximately 9 degrees; the asymmetry angle will vary, of course, depending upon the exact geometry of the pontoon. The photovoltaic cell 100 remains below the pond's surface 22, providing passive cooling, for all operational sun heights.

Shadowing Effect Illustration

065 Shadow tolerance, as described above, reduces the deleterious effects of partial shading of a solar collection region by providing relatively uniform light distribution to the photovoltaic collection area even in the presence of partial shadowing. The uniform and expected nature of the shadowing that occurs on closely spaced pontoon solar collector roof lenses provides special opportunities for effecting shadow tolerance.

066 Fig 7 illustrates a problem with using a conventional, single focal point lens 120 for a solar collector subject to partial shading. Shadowed region 128 of the conventional lens 120 is as expected for a pontoon solar collector operating at 30 degree elevation, which corresponds to 50% shading of roof lens 120. The conventional lens maps the shaded region 128 onto the target 100 as dark region 126. The unobstructed portion of the lens 122 focuses its light on the upper half 124 of the target 100. Such uneven illumination of the photovoltaic cell will result in poor electrical energy generation efficiency and possible damage of the photovoltaic cell 100.

Offset Tile Fresnel Lens Design

067 Fig. 8 illustrates one embodiment of a shadow-tolerant lens 140 that may serve as a section of roof lens on a pontoon solar collector. In this embodiment, upper half 142 of the lens 140 is never shadowed by the neighboring pontoon solar collector, and

therefore the light from this entire subregion of the lens 140 is simply directed uniformly to the surface area of target cell 144. The lower half of the lens 146, at various times, may be partially or entirely shaded by the neighboring pontoon collector depending upon the sun elevation. The lower half of the offset tile-Fresnel lens 146 is tiled. Each tile (which is a contiguous subregion of the overall lens) directs the light it receives substantially uniformly toward the target. Thus, shading on any one tile affects light distribution on the target only according to the proportion of that tile area to the entire illuminated area of the lens 140. Accordingly, illumination irregularities are attenuated on the target just by virtue of using subregions, such as tiles, that each direct light uniformly to the target.

068 However, Fig. 8 also illustrates how offsetting tiles from one another, compared to an expected shadow line, can reduce target illumination imbalances even farther. Each tile is shown offset by 1/10 of a tile width for the tiles from 166 to 154. Looking at slices1/10 tile wide in each of those tiles, it will be seen that slices in adjacent tiles that fall along the expected shadow line each map to a different part of the target 144, effectively spreading out the uneven illumination over the entire surface of the target.

069 From one tile column 148, to the next tile column 150, the tiles in the columns are offset vertically from one another. The shading of the roof lens 140 by the neighboring pontoon solar collector creates a horizontal shade line 152. One-tenth of a tile height above the horizontal shade line 152 is a conceptual line 154 showing the upper limit of a conceptual composite tile 156. The light rays 160, 162 and 164, which have passed through the conceptual composite tile 156 are shown for tiles 166, 168 and 170. The corresponding locations where light is received by the photovoltaic cell 144 are shown as 172, 174 and 176. Light rays from only three tiles (166, 168 and 170) are shown for clarity, but when all ten columns of the conceptual composite tile 156 direct their portion of light rays towards the photovoltaic cell 144, the result is an evenly illuminated photovoltaic cell 144.

070 In the example lens that is illustrated, the largest illumination variation due to partial shading of the vertically offset tile lens occurs when 49.5 percent of the vertically offset tiled lens 140 is shaded, resulting in a variation in illumination of about two percent across the surface of the photovoltaic cell 144. When 0.5 percent of the vertically offset tile lens 140 is shaded, a one percent illumination variation across the surface of the target 144 results. Percent variation in illumination at the target is inversely related to the area of the subregions of the lens that remain evenly illuminated. The illumination variation at the photovoltaic cell due to lens shading relationship may be described by the following equation:

$$\%\ \text{illumination variation} = (10000/(Yn^2))$$

where $n > 1$, and represents the number of square tile rows across the region of the Fresnel lens focusing onto one target, and $100 > Y > 50$ represents the percentage of the roof lens that experiences solar radiation. This relationship holds for a square lens and tiles, with a point focus. Other relationships would hold for other shaped lenses and tiles, which still apply the above-described concept. Note that Fresnel lenses and Fresnel-like lenses are a very appropriate technology for roof lenses. Though not necessary, they are frequently used because they are generally less expensive than other types of lenses.

071 In another embodiment of the offset tile lens 140 the entire surface area of the lens 140 may be composed of offset tiles as shown in the roof lens of the pontoon solar collectors in Fig 1, which may simplify fabrication and assembly of the lens onto the pontoon solar collector 30. The tile size in such a lens may be the same size as the target size, with no magnification performed by each tile. Such a lens achieves concentration by the number of tiles directing light towards the target photovoltaic cell 144. In general, concentration will be equal to overall lens area divided by target area.

072 Fresnel lens technology allows magnification to be performed by each tile, enabling the number of tiles to be reduced. However, as the tile size on the lens is increased, the variation in illumination due to partial shading of the lens is also increased at the photovoltaic cell 144. For a given number of tiles, light magnification by each tile allows the photovoltaic cell 144 size to be reduced, which increases the overall magnification of the lens 140. Tile offset from column to column may be uniform, and helps achieve an even illumination at the photovoltaic cell 144. The size of the tile offset may be 1/n of the vertical height of a tile, where n is the number of square tiles in a row across the region of the Fresnel lens focusing on one photovoltaic cell. When n=10, meaning that there are ten columns of offset tiles directing light towards one photovoltaic cell, each tile may be offset 1/10 of the tile height from its neighbor to help effect uniform light distribution at the photovoltaic cell 144. Photovoltaic cell 144 would be placed in thermal contact with the heat exchange element 96 contained in Fig. 3, when applied to the pontoon solar collector 30.

073 Fig. 9 shows a perspective of an alternative embodiment of a shadow tolerant lens 180. Note that (though it is not a necessary condition), the shape of the target and the tiles intended to be shown is rectangular, nearly square. In this embodiment, the tiles are not offset from each other, but are aligned with each other in both axes. In this configuration, the roof lens area corresponding to a single photovoltaic cell is rotated. The amount of roof lens rotation may be adusted such that when the top left hand corner 181 of a row of tiles is just shaded by the left hand side of the neighboring collector's shade line 183, the right hand top corner of any other tile row is just shaded by the right hand edge of the shadow line 183. Fig. 9 shows the right hand top corner 182 that is just shaded by the horizontal shade line 183. This drawing shows rotation of the overall lens by an amount equivalent to one row of tile offset, but any integral number of tile row rotations will provide nearly perfect shadow tolerance. Two rows of tile rotation, for example, would cause the area near 184 to be just shaded by the right hand side of shade line 183. When using this type of rotation in the roof lens tile pattern, the target photovoltaic cell 144 may also be rotated to simplify mapping the light from tiles uniformly over the target. Rotation of the lens and cell provides a positional variation of the horizontal shadow line across each column of tiles, resulting in homogeneous concentrated light over the entire photovoltaic cell even when the lens is partly shaded along a line.

074 Shadow tolerance is only one benefit of the tiled lens approach to solar concentration. Tiling may also provide a more uniform illumination of the target compared to conventional Fresnel lens designs, which typically create a hot spot on a portion of the target. This hot spot degrades the overall performance of the cell by delivering too much energy to the very center of the cell, which raises the operating temperature and wastes concentrated energy that could have been used for energy generation if it were more evenly distributed across the target.

075 Fig. 10 shows a single Fresnel tile 190 of an offset tile Fresnel lens in relationship to a target 144. A light ray 192 is entering normal to the smooth outer surface 194 of the tile 190. As the light ray 192 exits the tile 190, the faceted face 195 bends the light ray 192 towards the photovoltaic cell 144. A normal vector 196 of the target 144 (presumed, for this purpose, to be parallel to the normal vector of the lens and thus of the smooth face 194) is shown as a reference indicating the amount of refraction taking place within the tile 190. Depending upon a position of tile 190 within the overall roof lens of which it is a part, the Fresnel facets within the tiles may need to be rotated to most easily achieve the correct direction of refraction to ensure the light is properly directed to the photovoltaic cell 144. The angle of each Fresnel facet will also need to be changed depending upon each tile's position on the roof lens. Magnification of the light passing through an individual tile can also change the Fresnel facet shape and orientation while still applying this principle. Facet size and number should be determined by lens fabrication factors while adhering to the lens features that provide point focused shadow tolerance.

076 To provide the feature of shadow tolerance, the shape of the tile does not have to directly correspond to the shape of the target. Rectangular (non-square) tiles on the lens may be used with a square target, with magnification along one axis (e.g., length or width) of the tile unequal to magnification in the perpendicular axis.

Line Focus Fresnel - Type Lens Design

077 Fig. 11 shows a line focused Fresnel roof lens 200 with a tiled refraction pattern. The tiled line focused lens 200 may have long narrow tiles 204, each running parallel to an expected shadow line 203 (e.g., created by the neighboring solar collector). The width of the narrow tiles 204 may be adjusted in relation to the photovoltaic target size and the amount of illumination variation that is acceptable for the photovoltaic target 202. To increase the tiled linear focus lens's ability to deliver homogeneous light when partially shaded, the narrow tiles 204 may be thinner than the width of the photovoltaic target, with each tile 204 comprised of a converging lens or negative focal line to fan the light out across the photovoltaic targets 202 (which is wider, in this case, than the tile) as shown in Fig. 11. The narrower each tile becomes, the smaller surface area percentage a single narrow tile will have in relation to the entire surface area of lens 200, reducing the effect of shadowing. The practical limit of this concept would involve each facet face of the linear Fresnel lens being curved in such a manner that each Fresnel facet distributes the light passing through its surface uniformly across the target, such that each Fresnel facet is a subregion for uniform distribution over the target. When one facet is partially shaded, the surface area of the facet is small compared to the illuminated portion of the overall lens, so that illumination variation at the photovoltaic target is minimal. Each the facet face could be shaped with a slight concave profile. The concave profile to cause the light passing through each facet to be evenly distributed on the photovoltaic target. The photovoltaic target 202 will be placed in thermal contact with the heat exchange element 96 shown in Fig. 3, and roof lens 200 will be positioned similarly as described with respect to the roof lens 24 in Fig. 3. Note that with long thin tiles, as shown in Fig. 11, a very slight rotation of the overall lens (and, generally, target too) with respect to the expected shadow line will enhance shadow tolerance even farther.

Optical Solar Tracking System-Elevation Configuration

078 Fig. 12 shows an elevation-tracking configuration of the optical solar tracking system 90 that has two major optical components, an accurate tracking subsystem 210 and a wide angle tracking subsystem 212. The accurate tracking subsystem 210 includes a shadow box 214 which has a slit 216 and filters 218, allowing filtered light rays from the sun 220 to pass through a window 222 on the top of the optical tracker chip 224 before striking a photosensitive linear array 226. The optical solar tracking system 90 may be directly attached to the inside of one end cap 28 in a pontoon solar collector, with the slit 216 running parallel to the pontoon solar collector elevation rotation axis 230, and with the window 222 of the optical tracker chip 224 oriented normal to the incident solar irradiance when the collector is aligned with the sun's position in the sky. This configuration allows the optical tracker chip 224 to gather useful information about the orientation of the pontoon solar collector 228 with respect to the sun's position.

079 The quality of sunlight reaching the photosensitive linear array 226 will vary due to atmospheric conditions and impurities, resulting in variable apparent sun shape. Light that passes thorough the filtered slit 216 in the shadow box 214 will be sensed by the photosensitive linear array 226 as a variable width lighted region 223, due to the atmospheric conditions and impurities affecting the sun's apparent shape. The variable width lighted region 223 will be sensed by the photosensitive linear array 226 and converted to electrical information about the sun's location and shape.

080 The light filter 218 over the shadowbox slit 216 may be used to eliminate much of the misleading "noise" light from the surrounding sky. The light quality algorithm contained in the optical tracker chip 224 determines an appropriate exposure time and evaluates the incoming light quality. The centering algorithm contained within the optical tracker chip 224 effectively reads the electrical information about the sun's location and proportionally activates the pontoon solar collector's motors to position the variable width lighted region 223, to the center of the photosensitive linear array 226.

081 In application, the slit 216 may be the only opening for light in the shadow box. The narrow acceptance angle of the accurate tracking subsystem 210 described above may be supplemented with a wide angle tracking subsystem 212 to facilitate sensing the sun throughout the range of motion of the pontoon solar collector. The wide angle tracking subsystem 212 includes a low sun sensor section 232 and a high sun sensor section 234. The high sun sensor section 234 may employ phototransistors (or other opto-electrical sensitive devices) 236,237,238, and partitions 240. These items may be positioned to determine when the sun is "higher" in the sky than can be sensed by the accurate tracking subsystem 210. Similarly, the low sun sensor portion 232 may consist of phototransistors or some other opto-electrical sensitive devices 242,243,244, and partitions 246, positioned to determine if the sun is "lower" in the sky lower than can be sensed by the accurate tracking subsystem 210. The phototransistors 236-238 and 242-244 may be wired to the optical tracker chip 224, which uses the information provided thereby to decide a direction of motion required to position the pontoon rotation within range of the accurate tracking subsystem 210.

082 A condition in which both phototransistor 236 and 242 receive sunlight at the same time may be recognized to trigger the accurate tracking subsystem 210 to begin controlling the collector's actuator, increasing the accuracy of the tracking. Since most elevation tracking systems have neighboring collectors, an optical blind 248 may be used to keep the lower sun sensor half 232 from "seeing" neighboring collectors and therefore providing false tracking information during low sun height operation. The optical blind 248 operates passively, with gravity acting upon the blind's counter weight 250 as it pivots around its axis 252 of rotation. As the pontoon solar collector 228 rotates around its axis, the optical blind 248 moves to shield phototransistors 244,243 and will ultimately shield a portion of phototransistor 242 when the pontoon solar collector has reached it minimum sun height tracking angle. As an alternative embodiment, the elevation tracking system could be attached to the exterior of a pontoon; additionally the motor/gearbox could also be mounted to the exterior of the pontoon solar collector.

083 Recent advancements in the semiconductor industry's development of systems on a chip (SoC) technology allows for a single integrated circuit to be used to detect incident sunlight, process the sun's location, determine the amount of positional correction required to align with the sun, and amplify a proportional output signal directly to an electro-mechanical actuator. The relatively simple nature of the centering algorithm assures its ability to be implemented by current SoC technology. The task of two-axis tracking can be effectively executed by tracking the sun with two, single-axis tracking systems. The addition of two subsystems for tracking the sun's position in the sky is easily offset by the simplicity and lower cost of the single axis tracking systems. The floating pontoon's concentrating roof lens and optical solar locating system both require a similar quality of sunlight to operate effectively so their use in the same solar energy system is a good match.

Optical Solar Tracking System-Azimuth Configuration

084 Fig. 13 shows an azimuth tracking application of the optical solar tracking system with its. The optical solar azimuth tracking system 50 may include three major optical components, an accurate tracking subsystem 260, a wide angle tracking subsystem 262, and a sun height detection system 264.

085 The accurate tracking subsystem 260 may include a shadow box 266 which has a slit 268 and filters 270, allowing filtered light rays 272 to pass through a window 222 on the top of the optical tracker chip 224 of the photosensitive before striking a photosensitive linear array 226. The optical tracker chip 224 may be angled relative to the bottom of the shadow box 273 to allow the optical tracker chip 224 to sense the light source azimuth for all operational sun heights of the pontoon solar collectors. The bottom 273 of the shadow box 266 may be directly attached to the base plate 51, which in turn may be connected to the pontoon solar collector array's perimeter ring, providing azimuth orientation information about the array alignment with respect to the sun.

086 When the sun's rays have been detected upon the photosensitive linear array 226 and the data processed, the optical tracker chip 224 will output appropriate electrical signals to the pontoon solar collector's azimuth actuator motor. The slit 268 in shadow box 266 may be the only light opening in the accurate tracking subsystem 260 portion of the shadow box 266. The narrow acceptance angle of the accurate tracking subsystem 260 described above may be supplemented with a wide angle tracking subsystem 262 to facilitate sensing the sun throughout the sky.

087 In an azimuth tracking application, the wide angle tracking subsystem 262 may be designed to sense the entire 360 degree sky, wide-range sensing which may be effected with a series of phototransistors, or any other appropriate opto-electrical sensing devices, all pointing radially outward with partitions between each device. Phototransistors 275 and 276 are shown making up part of the wide angle tracking subsystem and may be wired to the optical tracker chip 224, which includes simple Boolean logic to activate the pontoon solar collector's azimuth actuator motor. The actuator motor moves the collector towards the sun such that both phototransistors positioned around partition 286 are pointed directly at the sun, at which position the accurate tracking subsystem 260 may be engaged to increase the tracking accuracy. Partition 286 should be in line with the sun when the azimuth of the solar collector is aligned with the sun's rays, assuring that the shadow box's slit 268 is passing sunlight to the exact middle of the photosensitive linear array 226.

088 In an azimuth tracking application, for a given amount of misalignment between the collector's orientation and the sun's orientation in the sky, the duration of the tracker's output pulse width may be increased with increased sun height. A sun height detection system 264 wired to the optical tracker chip 224 enables the optical tracker chip 224 to sense the sun's height in the sky and increase the electrical pulse duration to the pontoon solar collector's azimuth actuator motor. The sun height detection system 264 may consist of phototransistors 288 thru 291 or some other opto-electrical sensitive devices, positioned beneath a window 292 within the sun height portion of the shadow box 266 which allows the sun's rays to strike different phototransistors when the sun is at different elevation angles to the detection system. Suns rays striking phototransistor (or other device) 288 indicate that the sun position requires an increase in the tracking pulse duration. Sun striking phototransistor (or other device) 289 and 290 indicate further error, and thus may cause larger increases in tracking pulse durations.

089 Circuitry within optical tracker chip 224 may implement the longer duration tracking pulses as higher sun heights are encountered. Phototransistor 291 may be placed relative to the window 292 in the shadow box 266 such that it will detect the sun only when the sun is at its zenith. This situation may cause the optical tracker chip 224 to quickly rotate the azimuth axis tracking system 180 degrees, in order to enable the elevation trackers to continue to follow the sun west.

Wide Angle Sensor/Accurate Sensor Interaction

090 Fig. 14 shows an effective overlap of angular ranges of optical sensitivity for the accurate tracking subsystem and the wide angle tracking subsystem in an elevation optical solar tracking configuration. The optical sensing range 300 of the accurate tracking subsystem is centered around the optical sensing range overlap 302 between the two optical sensing ranges 304 and 306, corresponding to the high sun sensor half and low sun sensor half of the wide angle tracking subsystem used in an elevation tracking configuration. When the sun angle is within one of the optical sensing ranges 304 or 306, the phototransistors (or other appropriate opto-electrical sensing devices) will provide a signal which may be interpreted as indicating that the optical tracker chip should move the pontoon solar collector's elevation motor/gearbox toward the optical sensing range overlap 302. Once the optical sensing range overlap position 302 is reached by the pontoon solar collector, the phototransistors will indicate to the optical tracker chip 224 that the sun is positioned within the accurate tracker's optical sensing range 300, and the accurate tracking subsystem may take over tracking control.

091 Fig. 15 is a plan view of an effective overlap of angular ranges of optical sensitivity for the accurate tracking subsystem and the wide angle tracking subsystem in an azimuth optical solar tracking configuration. The optical sensing range 308 of the accurate tracking subsystem is centered around the optical sensing range overlap 310 of the optical sensing range 312 of the wide angle tracking subsystem used in an azimuth tracking configuration. When the sun is sensed within the sensing range of the wide angle tracking subsystem 312, signals from the phototransistors (or other opto-electrical sensitive devices) will indicate to the optical tracker chip 224 to move the azimuth actuator of the pontoon solar collector array, until the optical sensing range overlap position 310 is reached by the collector. Once the optical sensing range overlap position 310 is reached by the pontoon solar collector array, the phototransistor signals will indicate to the optical tracker chip 224 that the sun is within the accurate tracker sensing range 308, and the accurate tracking subsystem may take over tracking control.

Accurate Sensor Operation

092 Fig. 16A and 16B show a functional block diagram of the optical solar tracking system showing the functions used in the light quality algorithm and centering algorithm to process optical data from various sensors into an output electrical control signal used by the solar collector's actuator to facilitate accurate tracking of the sun's position in the sky. The wide-angle sensors 320, 321, 322, and 323 are used by the wide angle subsystem, to direct the tracker close enough to the sun that the photosensitive linear array 226 can begin to accurately track the sun's position. Simple Boolean logic is used to translate the wide-angle sensor data into logical outputs, which are logically OR-ed 328, 329 with the accurate tracking subsystem outputs before being amplified by the Variable Pulse Width Output Signal Amplifier 330. When both the Forward East Wide Angle Sensor 321 and the Forward West Wide Angle Sensor 322 are illuminated by the sun at the same time, corresponding to the optical sensing range overlap described in Figs 14 and 15, which indicates that the wide angle tracker is effectively in line with the sun and outputs a logic "1" on signal 332, and enables the accurate tracking subsystem to begin operation.

Algorithm to Determine Appropriate Exposure Time and Evaluate Incident Light Quality

093 In Fig 16A and 16B, light rays that have passed through a filtered slit in a shadow box strike a photosensitive linear array 226. An exposure measurement cycle is initiated by clearing the photosensitive linear array 226 of any past light exposure effects and setting the exposure timer 334, to a minimum count value. When the exposure timer 334 times out, indicating sufficient exposure time has elapsed, electrical charge proportional to the amount of sunlight striking each segment of the photosensitive linear

array 226 is loaded into a sample and hold register 336. The contents of the sample and hold register 336 are loaded into a shift register 338, which sequentially outputs an analog voltage proportional to the amount of sunlight seen by each segment of the photosensitive linear array 226. The output of the shift register 338 is digitized bit by bit with a voltage comparator 340, using an external reference voltage 341 to define the threshold voltage required to indicate the presence of light on each photosensitive linear array segment.

094 For the purposes of this description, a logical "1" represents a photosensitive linear array segment that has experienced sunlight during an exposure period. Depending upon the type of photosensitive linear array 226 used, the logic value representing the presence of light could be logic "0". If a reverse logic light sensing technology is used, the following algorithm would be unchanged, but the logic values would be reversed throughout the following description.

095 As each segment's voltage is digitized by the voltage comparator 340 and put into the serial data stream, three binary counters monitor and record the data. The ONE Counter 342 monitors the serial data stream, counting the number of photosensitive linear array segments that experienced sufficient light to be registered as a logical "1" by the voltage comparator 340. Proper exposure of the photosensitive linear array 226 can be determined when the number of logical "1's" is within a predetermined range. The ONE Count Minimum Comparator 346 holds a binary count value corresponding to the number of logical "1's" expected from the photosensitive linear array 226 when exposed to the clearest of sky conditions. The ONE Count Maximum Comparator 344 holds a binary count corresponding to the number of logical "1's" expected from the photosensitive linear array 226 when exposed to the most hazy conditions that accurate tracking can be reliably performed. After all the segments of the photosensitive linear array 226 have been digitized and counted for the minimum exposure time, the content of the ONE Counter 342 is loaded into the ONE Count Maximum Comparator 344 and the ONE Count Minimum Comparator 346.

096 The results of the ONE Count comparisons are routed to the Exposure/Subtraction Control 348, which records the results for the minimum exposure time as underexposed if the number of logic "1's" sensed by the photosensitive linear array was too low to surpass the ONE Count Minimum. Within a fraction of a second, the results of multiple exposures, each with progressively longer exposure time periods, are sensed, digitized, compared, and then recorded in Exposure/Subtraction Control. As the exposure time is increased, the data sensed by the photosensitive linear array will vary depending upon the external light conditions. As the exposure times continue to increase, the photosensitive linear array will become overexposed by the incident sunlight. Overexposure is indicated by the number of logic "1's" sensed by the photosensitive linear array exceeded the ONE Count Maximum. Because all the exposures are performed within a fraction of a second, the variation in the sky's conditions can be considered negligible.

097 There will be some exposure times that allow the photosensitive linear array to record a number of logical "1's" between the ONE Count Minimum Compare and the ONE Count Maximum Compare values. When an exposure is between the maximum and minimum, the exposure can be considered an appropriate exposure for the current light conditions. The number of appropriate exposures obtained during the increasing exposure time process will give an indication of the light quality being experienced by the photosensitive linear array. If only one appropriate exposure is measured, that would indicate that the incident light conditions are diffused with little columnar light coming directly from the sun. If there were three or four exposures considered appropriate for the current incident light conditions, it would indicate good columnar light being received. From this information the Exposure/Subtraction Control 348 can determine whether to attempt to track the sun because of good light quality or wait for

changing sky conditions before making any actuation changes. This reduces the controller's likelihood of being fooled by bright spots in the sky or hunting for the sun when it is behind thick clouds.

098 With several appropriate exposures measured, the Exposure/Subtraction Control 348 can determine the best exposure time for the current sky conditions. The exposure time determined the best is then re-loaded into the Exposure Timer 334 and another exposure is taken. The results of the best exposure are sensed by the photosensitive linear array 226 and digitized as described above. Comparisons of the ONE Counter data are once again performed on the best exposure and if it is determined to be within the appropriate range, the exposure measurement cycle is complete and the algorithm that generates the actuator motor control signal can begin. If the sky conditions have changed to the point that the best exposure time does not create an appropriate exposure, the exposure measurement cycle will restart with the minimum exposure time and re-evaluate the sky's condition.

Algorithm to Transform Optical Data into Proportional Motor Control

099 Once the results of the best exposure are sensed by the photosensitive linear array 226, they are digitized and placed onto a serial data stream as described above. While the ONE Counter 342 is monitoring the serial data stream, a Pre-ONE ZERO Counter 352 and a Post-ONE ZERO Counter 354 are also monitoring the serial data stream. The Pre-One Zero Counter 352 counts the number of logical "0's" sensed by the photosensitive linear array 226 during the measurement cycle, before a series of logical "1's" are encountered in the serial data stream. The Pre-One Zero Counter 352 data gives positional information about where the rays of sunlight light begin on the photosensitive linear array 226. The Post-One Zero Counter 354 monitors the serial data stream for each segment produced by the voltage comparator 340 and only begins to count the number of logical "0's" in the serial data stream, following the series of logical "1's" corresponding to the sunlight which passed through the slit and filters in the shadowbox before striking the photosensitive linear array 226. The Post-One Zero Count 354 data gives positional information about where the rays of sunlight end on the photosensitive linear array 226.

0100 If the comparisons of the ONE Counter 342 indicate the best exposure is still appropriate, the Exposure/Subtraction Control 348 initiates the Binary Subtraction With Borrow 350. The binary subtraction determines the difference between the contents of the Pre-ONE ZERO Counter 352 and the Post-ONE ZERO Counter 354. Since these counters hold positional information about the location of the logical "1's" block on the photosensitive linear array, the difference between these two counters will represent the amount of movement required to align the shadowbox with the sun's rays. When the Binary Subtraction With Borrow Unit 350 subtracts the binary contents of the Post-One Zero Counter 354 from the binary contents of the Pre-One Zero Counter 352 the resultant is loaded into the shift register 356. Once loaded, the shift register 356 is shifted one bit to the right effectively dividing the contents of the shift register by two. The binary value of the sign of the subtraction is held in the sign flip-flop 358 and indicates the direction of the tracking motion required to align the collector to the sun's rays.

0101 At this point in the centering algorithm, shift register 356 contains the binary difference between the number of zeros (number of photosensitive liner array segments that have not been exposed to sunlight) on each side of the variable width light spot that was sensed by the photosensitive linear array. If there were an equal number of zeros sensed on each side of the variable width light spot, that would indicate that the variable width light spot is in the middle of the photosensitive array and no motion is required to align with the suns rays and shift register 356 following the centering algorithm would contain a binary zero value. If there were twenty two more zeros in the Post One Zero Count 354 than in the Pre One Zero Count 352, it would indicate that the collector needed to move eleven segments to the east, to center the variable width light spot on the photosensitive array and following the

centering algorithm, shift register 356 would contain a binary value of eleven, with a negative sign flip flop 358, indicating direction. If there were twenty two more zeros in the Pre One Zero Count 352 than in the Post One Zero Count 354, it would indicate that the collector needed to move eleven segments to the west and the sign flip flop 358 would indicate a positive sign.

0102 The sun height sensors 360 monitor the sun's elevation in the sky and are wired to the input of the shift register control 362. In an azimuth tracking application, where high sun heights require a longer pulse duration to perform tracking, the shift register 356, can be instructed by the shift register control 362, to shift the shift registers contents towards the left by one two or three bits, effectively elongating the tracker's output pulse because of the height of the sun in the sky.

0103 Once the shift registers contents 356 have been shifted, its contents are loaded into a PWM count down timer 364, who's output goes high until the timer times out, at which point the PWM count down timer 364 output stays low until it is loaded again. Simple Boolean logic is implemented to turn the PWM count down timer 364 and sign 358 flip flop into discrete signals which are routed to the input of the Variable Pulse Width Output Signal Amplifier 330, which amplifies the signals to be used by the solar collector's actuator motor 366.

0104 Fig. 17a and 17B shows a flow chart showing the steps that the accurate tracking subsystem performs to translate the photosensitive linear array imagery data into solar collector proportional electrical actuator signals. Previous figures have described most of the process in detail. The decision box 370 is used to determine if the last exposure was taken as the best exposure determined by the Exposure/Subtraction control. If it was the best exposure time, and the One counter shows the exposure is not within acceptable limits, the exposure/subtraction controller is reset and the multiple exposure routine begins again. This loop allows the system to continually evaluate the sky's light condition without having to output actuator control signals during times of poor light quality. To remain within 1/10th of a degree in accuracy, the system must align with the sun's rays once every 24 seconds. This leaves a lot of time available to process sky conditions and determine the correct actuation needs. One condition that may require multiple samplings of incident sunlight is when the atmosphere varies as moisture levels between the sun and sensor are changing due to windy moist conditions. This type of condition could cause sensing errors from moment to moment. To reduce the effect of such conditions resulting in erroneous tracking, the centering algorithm could be performed a number of times in a short time period. The data could be compiled and averaged to generate a more reliable control signal to the collector actuators. A delay is shown for system response 374 to allow the solar collector to physically stabilize before beginning the next tracking adjustment. This delay could be used to ensure that the system is not continually modifying its position, as it only required periodically.

0105 Fig. 18 illustrates an exemplary interface of an optical solar tracking system with an optical tracker chip 224, which contains an optical window 222 to protect the photosensitive linear array 226 from damage. Sun height sensors 288 thru 291 interface directly with the optical tracker chip 224, each conveying information about the sun's elevation in the sky in an azimuth axis-tracking configuration. The wide-angle sensors 274 thru 285 could be wired together in sets of three to minimize the number of pins to the optical tracker chip and simplify the system wiring. Wide angle sensors 274 thru 276 face forward towards the east, wide angle sensors 283 thru 285, face forward towards the west, wide angle sensors 277 thru 279, face rearward towards the east, wide angle sensors 280 thru 282, face rearward towards the west. An externally available comparator reference voltage 341 allows the threshold voltage of the voltage comparison performed within the optical tracker chip 224 to be varied externally, depending upon sunlight filtering and application requirements. Exposure timing could be changed by an external timing resistor 382, depending upon the filtering used to reduce the sun's intensity before striking the photosensitive linear array 226. The duration of the tracker's output

pulse for a given amount of misalignment with the sun's rays could be modified to match the solar collector's actuator response by changing resistor 384. The settling time between measurement cycles could be modified by changing the value of resistor 386. The output amplifier could be external to the optical tracker chip to allow for various amplification requirements to be met and reduce the replacement cost associated with malfunctioned output transistors due to actuator shorts. Output FETs 388 thru 391, are shown in a typical H configuration, supplying drive current to the solar collector's actuator motor 366. In an alternative embodiment, FETs 388 thru 391 could be internalized into the SoC implementation reducing the interface electronics and simplifying the interface to the actuator motor 366.

Alternative Shadow Tolerance Embodiments

Electrical Shadow Tolerance Embodiments

0106 Shadow tolerance can be implemented by various methods, each of which avoids providing highly non-uniform illumination to an active photovoltaic (or other conversion) cell. Predictable, progressive shadowing along an expected path is not uncommon. One method for providing shadow tolerance in the presence of predictable, progressive shadowing is to include dividing the target into regions parallel to expected shadowing. The target regions may ordinarily be attached to each other via electronically controlled switches, such as FETs.

0107 When shading is known or expected, that portion of the target that is subject to shading may be separated from the active photovoltaic cell by readily designed electronics. Thereby, the effects of shadowing may be limited to a portion of the overall target conversion device. A conventional (typically Fresnel) lens may be used, as described with respect to Fig. 7, which shows a maximally shaded lens and target. The shadowed region 126 of the target may be divided into segments parallel to the shadow line. Four such sections are established, for example, each electrically separable from each other with FETs.

0108 Those segments that are partly shadowed will begin to perform less well. Sensing the impairment, the FETs connecting an affected section to the whole may be switched off, by any appropriate control such as an op amp sensing a reversal of current flow to the segment. The partly shaded region is thus isolated from the rest of the target device so as not to impair its efficiency. This has some advantages for cells that are more efficient with highly concentrated light, because the segments that remain active receive somewhat more concentrated light. Lens design and fabrication is simplified.

0109 Fig. 19 shows a photovoltaic cell 401 divided into six regions. The upper portion of the photovoltaic cell 403 is a single integral cell, which receives light from the upper half of a conventional lens, which is not expected to be shaded in typical application. The lower area of the cell is divided into five long narrow strip cells 405, 407, 409, 410 and 411, the longer axis of each being parallel to the expected shadow line. Whether wired in parallel or series, any appropriate method may be employed to isolate each strip cell from the operating portion of the overall cell 401 when it is partly shadowed.

0110 One wiring approach would be to connect each strip cell to a power bus through low voltage drop diodes such that, when properly illuminated, power that is generated by the strip cell reaches a power collection bus through the diode. When the strip cell is shaded, however, the diode keeps the power on the power bus from entering the shaded strip cell and consuming power. The low voltage drop diode may be replaced by an active ideal diode consisting of a low voltage op-amp controlling a field effect transistor FET, the devices configured to operate as a nearly ideal diode, reducing power loss associated with a diode voltage drop.

0111 Similar approaches may be used after connecting corresponding segments of a number of photovoltaic devices. Thus, the photovoltaic device shown in Fig. 19 may be repeated at intervals along an expected shadow line, as would occur in a pontoon solar collector system. All segments of all photovoltaics in the pontoon corresponding to segment 411 may be connected in series, and similarly for all segments corresponding to segment 410, and so on. All such series-connected segments may be treated as a single segment, for switching purposes, reducing the number of switches and op amps that is required, and increasing the voltage levels so that sensing is simplified. As output falls below a certain level, the series connected segment may be disconnected so as not to absorb power.

0112 Moreover, higher voltages in the series-connected format permit the use of simple flyback boost techniques to be used to obtain partial power from series segments whose power output has dropped off, but not declined to zero. A series diode (or equivalent) and flyback secondary winding may remain passive during normal operation. Upon the output dropping below a desired level, charge from the segment string may be diverted to a flyback transformer primary winding, then released such that the power is transferred to the flyback secondary that is in series with the segment string. In this, or another manner, extra voltage may be provided (at least part of the time), as necessary to bring the series segment to a voltage at which it can contribute power to the grid. These techniques are well known in power supply technologies, and new techniques may also be developed. Accordingly, specific techniques are not illustrated in detail herein.

Secondary Optics

0113 Fig. 20 shows one embodiment of secondary optics that may be used to facilitate shadow tolerance in a solar collector. Using a conventional point source Fresnel lens (such as illustrated in Fig. 7), incoming light rays 421, 423 and 425 would only illuminate the right half of the photovoltaic target shown in Fig. 20. A secondary optic 430 having an index of refraction greater than one may be added to the light path between the Fresnel lens and the target photovoltaic cell. The shape of the right half of the secondary optic 430 allows the light between light rays 421 and 425 to hit the entire photovoltaic cell uniformly. This region of light corresponds to the portion of the Fresnel lens that does not experience shade during normal operation. The light rays between 425 and 429 are refracted by the left half of the secondary optic 430 toward the photovoltaic target. The left half to the secondary optic is divided into facets. Each facet is shaped to deliver the light passing through the facet to the photovoltaic cell uniformly. Light rays 426 through 428 pass through one facet of the secondary optics before arriving at the photovoltaic cell 100. The light passing through the left half of the secondary optic represents the region of the Fresnel lens that will be variably shaded during normal operation. If three facets are shaded the remaining seven facets deliver homogeneous light to the photovoltaic cell 100.

0114 The overall effect of the secondary optics is to provide shade tolerance by minimizing the amount of illumination variation of the photovoltaic cell due to variable shading of a primary, conventional lens. Increasing the number of facets will decrease the variation in photovoltaic illumination. A difference between secondary and primary optics, in this context, is that primary optics are farther from the target than are secondary optics. Also, primary optics used with two-axis tracking systems are designed to accept light from primarily a single direction or "incoming light axis." Secondary optics, on the other hand, receive light at a variety of angles as a result of refraction by the primary optics.

Subdivided Subregions

0115 Another alternative embodiment of a shadow tolerant lens involves a thin horizontal strip of the roof lens surface including a multitude of individual regions, which may be called "subsubregions." Each subsubregion is a small refractive surface,

capable of delivering the light that passes through the region to the target, but is not intended to deliver light uniformly over an entire surface of the target. Instead, the summation of light from a particular group of subsubregions will deliver light uniformly to the target. Such a particular group of subsubregions constitutes a subregion of the overall lens, and thus each subregion delivers light uniformly to the target.

0116 Referring to Fig. 21, a roof lens having a length L_L (typically parallel to the rotation axis of a pontoon solar collector) and a width W_L. Each subsubregion in a strip 457 of subsubregions is identified as either A, B, C or D, and directs incident light toward a portion of a target 100. In particular, A subsubregions direct incident light toward a T(A) subsection 450 of the target 100. Similarly, B subsections direct incident light toward a T(B) subsection of the target 100, and so on.

0117 An A subsubregion, a B subsubregion, and C subsubregion and a D subsubregion are all required to constitute a subregion that illuminates the target 100 uniformly. Note that, as illustrated, the four closest A, B, C and D subsubregions are not contiguous. Thus, there is no need for subregions to be contiguous, as is the case with tiles (although tiles are also subregions, of course). Indeed, the pattern of subsubregions may be appear substantially random, so long as groups of subsubregions constitute subregions that distribute light to the target uniformly.

0118 Note also that square subsubregions map to rectangular target subregions, illustrating that tiles, subregions, or subsubregions need not have the same aspect ratio of length to width as the target (or subtarget) to which they direct light. Forming the above stated regions with either a slight concave shape or a slight convex shape would allow each region in the thin horizontal strip to deliver its light uniformly to the entire target further increasing the shadow tolerance of the lens.

Secondary Reflection

0119 Fig. 22 illustrates secondary reflection in combination with a point focus or line focus roof lens to enhance efficiency. When a ray of light 501 strikes the photovoltaic cell 100, sometimes it will reflect off the surface of the cell 100. To increase the chances of using this reflected sunlight, a secondary reflector 503 may be placed around the cell to redirect the reflected sunlight back onto the cell 100. Fig 21 shows one embodiment. There, a single light ray 501 is being redirected back to the surface of cell 100. The inner surfaces of the secondary reflectors 503 and 505 are preferably highly reflective so as to efficiently direct the stray light reflecting off the cell back towards the cell's surface. Secondary reflectors 503 and 505 are designed to avoid the incoming light from the roof lens. For a point focus application, the secondary reflector may be rotated around an axis perpendicular to the center of the photovoltaic cell 100. In a line focus application the secondary reflector may be extruded in a direction normal to the drawing page. The structure of the secondary reflector may also be used to position secondary optics.

0120 The foregoing description includes representative embodiments and some variations. It is impractical to disclose and discuss all useful variations, but the intent of providing a representative selection of variations is to illustrate that the invention is broadly understood by the inventor. Accordingly, the invention is defined only by the claims, which follow, plus any others, which may subsequently be drawn, and is not to be limited by any details of the disclosed embodiments, except insofar as they are claimed. All embodiments described by elements that fall with the range of equivalency of elements of the below claims are considered by the inventor to fall within the scope of the claimed invention.

CLAIMS

What is claimed is:

1. A solar converter apparatus for converting incoming light to electricity, comprising:
   a) a support structure for floating on a liquid bath, the structure having:
      i) a substantially fixed relationship to an incoming light axis that is parallel to useful incoming light,
      ii) an elevation rotation axis at a fixed azimuth alignment angle from the incoming light axis, the support structure being rotatable about the elevation rotation axis, and
      iii) guidance interface features connecting the support structure to a guidance frame that aligns the elevation rotation axis at the fixed azimuth alignment angle to an azimuth of the source of incoming light, and that provide a rotation reference for the support structure rotation about the elevation rotation axis to align the incoming light axis with the source of incoming light;
   b) at least one photovoltaic conversion device mounted within the support structure and adapted for converting concentrated sunlight into electricity; and
   c) a lens coupled to the support structure for guiding light that is parallel to the incoming light axis and is received over a receiving region toward a conversion device that is mounted within the support structure, the conversion device having an active area that is smaller than an area of the receiving region.

2. The apparatus of Claim 1, wherein (d) the liquid bath is a coolant that provides primary cooling of the conversion device through thermal contact with an exterior of the support structure.

3. The apparatus of Claim 1, wherein (d) the support structure is a first support structure, and is disposed in contact with a liquid bath in an array of support structures, substantially abutting adjacent support structures that each have an elevation rotation axis parallel to and in a plane with the elevation rotation axis of the first support structure.

4. The apparatus of Claim 1, wherein (d) light parallel to the incoming light axis that enters with uniform density across an entire surface of the lens exits the lens at angles with respect to the incoming light axis, with the average of all such exiting light angles defining a light delivery axis, and the light delivery axis has a significant non-zero angle with respect to the incoming light axis.

5. The apparatus of Claim 1, wherein (d) the receiving region of the lens is subject to shadowing that causes substantially non-uniform illumination of the receiving region of the lens, and the lens cooperates with the one or more converter devices to avoid substantially non-uniform illumination of operating photovoltaic conversion devices due to such shadowing.

6. The apparatus of Claim 5, wherein (e) the lens includes a plurality of subregions, and each subregion is configured to direct light substantially uniformly toward an entire surface of at least one corresponding photovoltaic conversion device.

7. The apparatus of Claim 1, wherein (d) the support structure floats in a coolant bath that has an average surface plane, and the photovoltaic converter devices are mounted on corresponding portions of the support structure that are below the coolant bath average surface plane for all light source elevation angles within 45 degrees from vertical.

8. The apparatus of Claim 7, wherein (e) the corresponding portions of the support structure are below the coolant bath average surface plane for all light source elevation angles within 60 degrees from vertical.

9. The apparatus of Claim 2, 3, 4, 5, 6, 7 or 8, wherein the frame structure is a pontoon having a light entry side opening that is substantially sealed by one or more lenses.

10. An apparatus according to Claim 9, wherein the one or more lenses occupy substantially an entire light entry side profile of the support structure so as to guide, toward a converter device, substantially all light arriving parallel to the incoming light axis that is incident upon the solar converter apparatus and is not reflected from a surface of a lens.

11. An apparatus according to Claim 9, wherein the support structure is part of an array of a plurality of solar converter apparatus support structures, each having a corresponding elevation rotation axis, that are all rotated about the corresponding elevation rotation axis by a common drive system to effect elevation alignment.

12. An apparatus according to Claim 9, wherein the support structure is part of an array of a plurality of solar converter apparatus support structures that each have a corresponding elevation rotation axis and a separate elevation angle drive system for rotating the support structure about the corresponding elevation rotation axis with respect to the positional reference to effect elevation alignment.

13. An apparatus according to Claim 9, further comprising a light source direction sensor mounted within the pontoon.

14. An apparatus according to Claim 9, wherein the pontoon includes a plurality of collector sections spaced along a length of the pontoon, each collector section including a collector section lens area directing light that arrives parallel to the incoming light axis toward a converter device area corresponding to the collector section.

15. The apparatus of Claim 3, 4, 5, 6, 7 or 8, wherein the support structure floats in a coolant bath that cools the photovoltaic conversion device via thermal contact with the support structure.

16. The apparatus of Claim 2, 4, 5, 6, 7 or 8, wherein the support structure is a first support structure, and is disposed within an array substantially abutting adjacent support structures that each have an elevation rotation axis parallel to and in a plane with the elevation rotation axis of the first support structure.

17. The apparatus of Claim 2, 3, 5, 6, 7 or 8, wherein light parallel to the incoming light axis that enters with uniform density across the surface of the lens exits the lens at an angle with respect to the incoming light axis, with the average of all such exiting light forming a light delivery axis having a significant non-zero angle with respect to the incoming light axis.

18. The apparatus of Claim 2, 3, 4, 7 or 8, further comprising at least one shadow-compensating lens configured to distribute sunlight arriving at each of a plurality of subregions of the shadow-compensating lens substantially uniformly over an entire surface of a corresponding conversion device, such that light density across the surface of the corresponding conversion device is substantially unaffected by partial shadowing of the shadow-compensating lens.

19. The apparatus of Claim 2, 3, 4, 5 or 6, wherein the support structure floats in a coolant bath that has an average surface plane, and the photovoltaic converter devices are mounted on corresponding portions of the support structure that are below the coolant bath average surface plane for all light source elevation angles within 45 degrees from vertical.

20. The apparatus of Claim 2, 3, 4, 5 or 6, wherein the support structure floats in a coolant bath that has an average surface plane, and the photovoltaic converter devices are mounted on corresponding portions of the support structure that are below the coolant bath average surface plane for all light source elevation angles within 60 degrees from vertical

21. The apparatus of Claim 2, wherein

e) the support structure is a first support structure, and is disposed within an array substantially abutting adjacent support structures, each adjacent support structure having an elevation rotation axis parallel to and in a plane with the elevation rotation axis of the first support structure;

f) the support structure floats in a coolant bath that has an average surface plane, and the photovoltaic converter devices are mounted on corresponding portions of the support structure that are below the coolant bath average surface plane for all light source elevation angles within 60 degrees from vertical; and

g) the fixed azimuth alignment angle is approximately 90 degrees.

22. A method of collecting incoming light for conversion to electricity, comprising:

a) mounting a conversion device at a mounting site within a support structure having an elevation rotation axis;

b) coupling a lens to the support structure to concentrate and guide incident light arriving parallel to an incoming light axis toward the conversion device;

c) floating the support structure on a liquid bath;

d) aligning the support structure so that the elevation rotation axis is at an azimuth alignment angle with respect to a source of light energy; and

e) rotating the support structure about the elevation rotation axis to align the incoming light axis toward the source of light energy.

23. The method of Claim 22, further comprising (f) cooling the conversion device primarily through thermal contact between the liquid bath and an exterior of the support structure.

24. The method of Claim 22, wherein the support structure, lens and conversion device are part of a first collection pontoon, further comprising (f) substantially abutting the first collection pontoon in an array with adjacent collection pontoons that each have an elevation rotation axis parallel to and in a plane with the elevation rotation axis of the support structure of the first collection pontoon.

25. The method of Claim 22, wherein a light delivery axis is defined as a line, intersecting the incoming light axis at a center of the lens and having an angle with respect to the incoming light axis that is equal to an average angle of exiting light that arrived parallel to the incoming light axis and uniformly distributed over an entire surface of the lens, further comprising (f) configuring the lens to have the light delivery axis at a significantly non-zero angle with respect to the incoming light axis.

26. The method of Claim 22, wherein the lens has a light receiving region, further comprising (f) intermittently subjecting the light receiving region of the lens to partial shadowing, and (g) incorporating into the receiving region a multiplicity of receiving subregions

that each receive light arriving parallel to the incoming light axis, and that each direct such received light substantially uniformly toward an entire surface of a conversion device common to the receiving subregions.

27. The method of Claim 22, wherein the liquid bath is a coolant bath having an average surface plane, further comprising (f) positioning the conversion device mounting site below the coolant bath average surface plane for all light source elevation angles within 45 degrees from vertical.

28. The method of Claim 22, wherein the liquid bath is a coolant bath having an average surface plane, further comprising (f) positioning the conversion device mounting site below the coolant bath average surface plane for all light source elevation angles within 60 degrees from vertical.

29. The method of Claim 23, 24, 25, 26, 27 or 28, wherein the frame structure is a pontoon having a light entry side opening, further comprising (g) substantially sealing the pontoon light entry side opening with one or more lenses.

30. A method according to Claim 29, wherein the pontoon has a profile on the light entry side, further comprising (h) covering substantially all of the light entry side profile with the one or more lenses, thereby guiding substantially all light incident upon the pontoon light entry side that arrives parallel to the incoming light axis and that is not reflected from a lens surface toward a converter device.

31. A method according to Claim 29, further comprising (h) arranging a multiplicity of pontoons in an array of pontoons each having a corresponding elevation rotation axis, and (i) rotating the multiplicity of pontoons about their corresponding rotation axes by means of a common elevation rotation drive system to effect elevation alignment of the multiplicity of pontoons.

32. A method according to Claim 29, further comprising (h) arranging a multiplicity of pontoons in an array of pontoons each having a corresponding elevation rotation axis, and (i) rotating each pontoon individually about its corresponding elevation rotation axis by means of a separate elevation rotation drive system to effect elevation alignment of the multiplicity of pontoons.

33. A method according to Claim 32, further comprising incorporating a light source direction sensor within each pontoon.

34. A method according to Claim 29, further comprising (h) spacing a plurality of collector sections along a length of the pontoon, each collector section including a collector section lens area to direct light that arrives parallel to the incoming light axis toward a converter device area corresponding to the collector section.

35. The method of Claim 24, 25, 26, 27 or 28, further comprising (g) cooling the conversion device primarily through thermal contact between the liquid bath and an exterior of the support structure.

36. The method of Claim 23, 25, 26, 27 or 28, wherein the support structure is a pontoon, further comprising (g) substantially abutting an array of pontoons that each have a corresponding elevation rotation axis parallel and in a plane with each other elevation rotation axis.

37. The method of Claim 23, 24, 26, 27 or 28, wherein light parallel to the incoming light axis that enters with uniform density across the surface of the lens exits the lens at an angle with respect to the incoming light axis, and the average of all such exiting light

forms a light delivery axis, further comprising (g) configuring the lens to have a significantly non-zero angle between the light delivery axis and the incoming light axis.

38. The method of Claim 23, 24, 25, 27 or 28, further comprising (g) distributing light from each of a multiplicity of receiving subregions of a shadow-compensating lens substantially uniformly over an entire surface of a corresponding conversion device, the light having arrived parallel to the incoming light axis, such that light density across the surface of the corresponding conversion device is substantially unaffected by partial shadowing of the shadow-compensating lens.

39. The method of Claim 23, 24, 25 or 26, wherein the liquid bath has an average surface plane, further comprising (f) positioning the conversion device mounting site to be below the coolant bath average surface plane for all light source elevation angles within 45 degrees from vertical.

40. The method of Claim 23, wherein the support structure, lens and conversion device are part of a first collection pontoon floating on the liquid bath, further comprising:

g) substantially abutting the first collection pontoon in an array with adjacent collection pontoons that each have an elevation rotation axis parallel to and in a plane with the elevation rotation axis of the support structure of the first collection pontoon;

h) positioning the conversion device mounting site below an average surface plane of the coolant bath for all light source elevation angles within 60 degrees from vertical; and

i) configuring each collection pontoon to have an azimuth alignment angle of approximately 90 degrees.

41. A lens device for directing light to a solar energy collection device, the lens device comprising

a) an overall light-receiving region that directs incident light toward an energy collection target; and

b) a plurality of light-receiving subregions of the overall region; wherein

c) each subregion is configured to distribute light substantially uniformly toward the target.

42. The lens device of Claim 41, wherein the lens is a primary lens configured to receive light substantially parallel to an incoming light axis over the overall light-receiving region.

43. The lens device of Claim 41, wherein the lens is a secondary lens configured to receive light incident to a first portion of the lens that is substantially non-parallel to light received incident to a different second portion of the lens.

44. The lens device of Claim 41, wherein each subregion has borders that are substantially parallel to a corresponding border of the energy collection target.

45. The lens device of Claim 41, wherein each subregion further comprises subsubregions, each subsubregion being configured to direct incident light toward a specific subtarget that is a portion less than a whole of the energy collection target.

46. The lens device of Claim 45, wherein two different subsubregions that are not adjacent in a length direction direct light to two different corresponding subtargets that are adjacent in the length direction.

47. The lens device of Claim 41, wherein each subregion further comprises subsubregions, each subsubregion being configured to direct incident light toward a specific subtarget that is a portion less than a whole of the energy collection target, wherein subsubregions of a subregion are discontiguous from each other.

48. The lens device of Claim 41, wherein each subregion further comprises subsubregions, each subsubregion being configured to direct incident light toward a specific subtarget that is a portion less than a whole of the energy collection target, wherein all subsubregions of a particular subregion are contiguous with another subsubregion of the particular subregion.

49. The lens device of Claim 41, wherein each subregion is a tile, and adjacent tiles are offset from each other with respect to an expected shadow line.

50. The lens device of Claim 41, wherein each subregion is a tile in a regular array that repeats along a repetition axis, and the repetition axis is disposed diagonally with respect to an expected shadow line.

51. The lens device of Claim 41, wherein each subregion is a tile, and each tile includes a plurality of Fresnel facets.

52. The lens device of Claim 41, 42, 43, 44, 45, 46, 49, 50 or 51, wherein each subregion is a tile having a length that is L_T times a length of the target and a width that is W_T times a width of the target, and L_T is not equal to W_T.

53. The lens device of Claim 41, wherein (d) each subregion is a single Fresnel facet.

54. The lens device of Claim 41, wherein each subregion is a tile having a length that is L_T times a length of the target and a width that is W_T times a width of the target, and

d) L_T for one tile is unequal to L_T for another tile, or

e) W_T for one tile is unequal to W_T for another tile.

55. The lens device of Claim 41, wherein

d) the overall lens includes a plurality of subregions;

e) each subregion is a tile having a width that is W_T times a width of the target;

f) W_T is less than unity; and

g) light entering each subregion in parallel diverges such that the light is distributed substantially uniformly across the full width of the target.

56. The lens device of Claim 41, wherein (d) the overall lens region is substantially composed of tile subregions having similar size.

57. The lens device of Claim 41, wherein (d) the overall lens device has a length that is L_L times a length L_T of the target and a width that is W_L times a width of the target, and (W_L / L_L) is greater than 4.

58. The lens device of Claim 57, wherein (e) the overall lens length L_L is substantially equal to the length L_T of the target.

59. The lens device of Claim 58, wherein (f) the energy collection target includes a plurality of discrete solar energy collection subdevices each having a device width W_D and a device length along a longitudinal axis, and the plurality of discrete subdevices is

disposed adjacent one another longitudinally to form a substantially contiguous line of devices having an effective overall length L_E that is greater than ($10 * W_O$).

60. The lens device of Claim 58, wherein (f) the energy collection target is a portion, less than a whole, of an energy collection device that has an overall length L_C greater than the length L_T of the target.

61. A method of directing light to a solar energy collection device to reduce shadow susceptibility, the method comprising:

a) directing light toward an energy collection target through an overall light-receiving region of a lens; and

b) configuring a plurality of light-receiving subregions of the overall region to each individually distribute light uniformly toward substantially an entirety of the target.

62. The method of Claim 61, wherein the lens is a primary lens configured to receive light substantially parallel to an incoming light axis over the overall light-receiving region.

63. The method of Claim 61, wherein the lens is a secondary lens, further comprising delivering light to the lens after it traverses a primary lens.

64. The method of Claim 61, wherein step (b) further comprises configuring each subregion to have borders that are substantially parallel to a corresponding border of the energy collection target.

65. The method of Claim 61, further comprising

c) establishing a multiplicity of subsubregions within each subregion, and

d) configuring each subsubregion to direct incident light toward a specific subtarget that is a portion less than a whole of the energy collection target.

66. The method of Claim 65, further comprising configuring two different subsubregions that are non-adjacent in a length direction so as to direct light to two different corresponding subtargets that are adjacent in the length direction.

67. The method of Claim 61, wherein each subregion is a tile, further comprising (c) offsetting adjacent tiles are offset from each other with respect to an expected shadow line.

68. The method of Claim 61, further comprising

c) disposing each subregion as a tile in a regular array that repeats along a repetition axis, and

d) disposing the array repetition axis diagonally with respect to an expected shadow line.

69. The method of Claim 61, further comprising creating each subregion as a tile composed of a plurality of Fresnel facets.

70. The method of Claim 61, 62, 63, 64, 67, 68 or 69, further comprising configuring each subregion as a tile having a length that is L_T times a length of the target and a width that is W_T times a width of the target, with L_T equal to W_T.

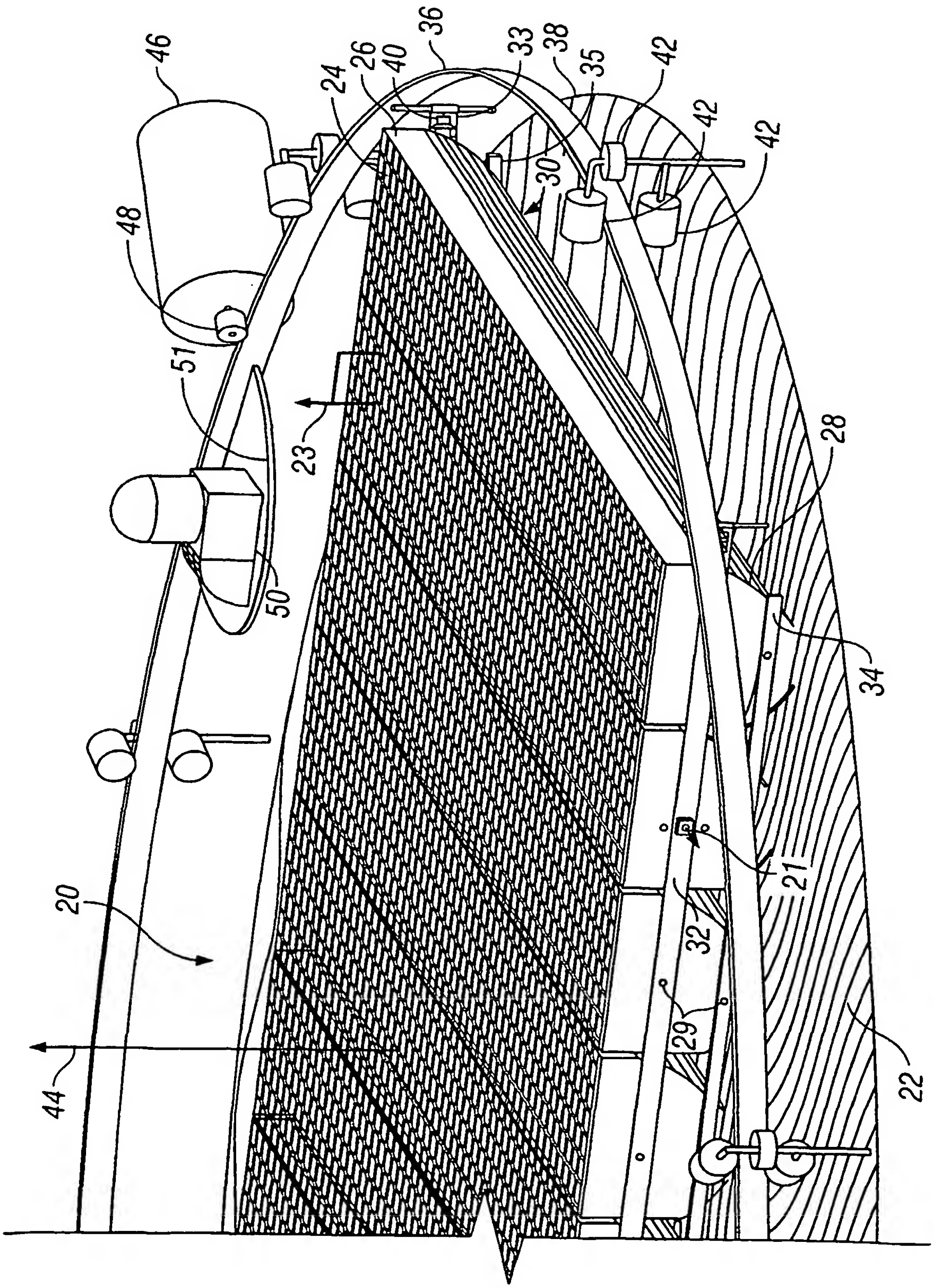

FIG. 1

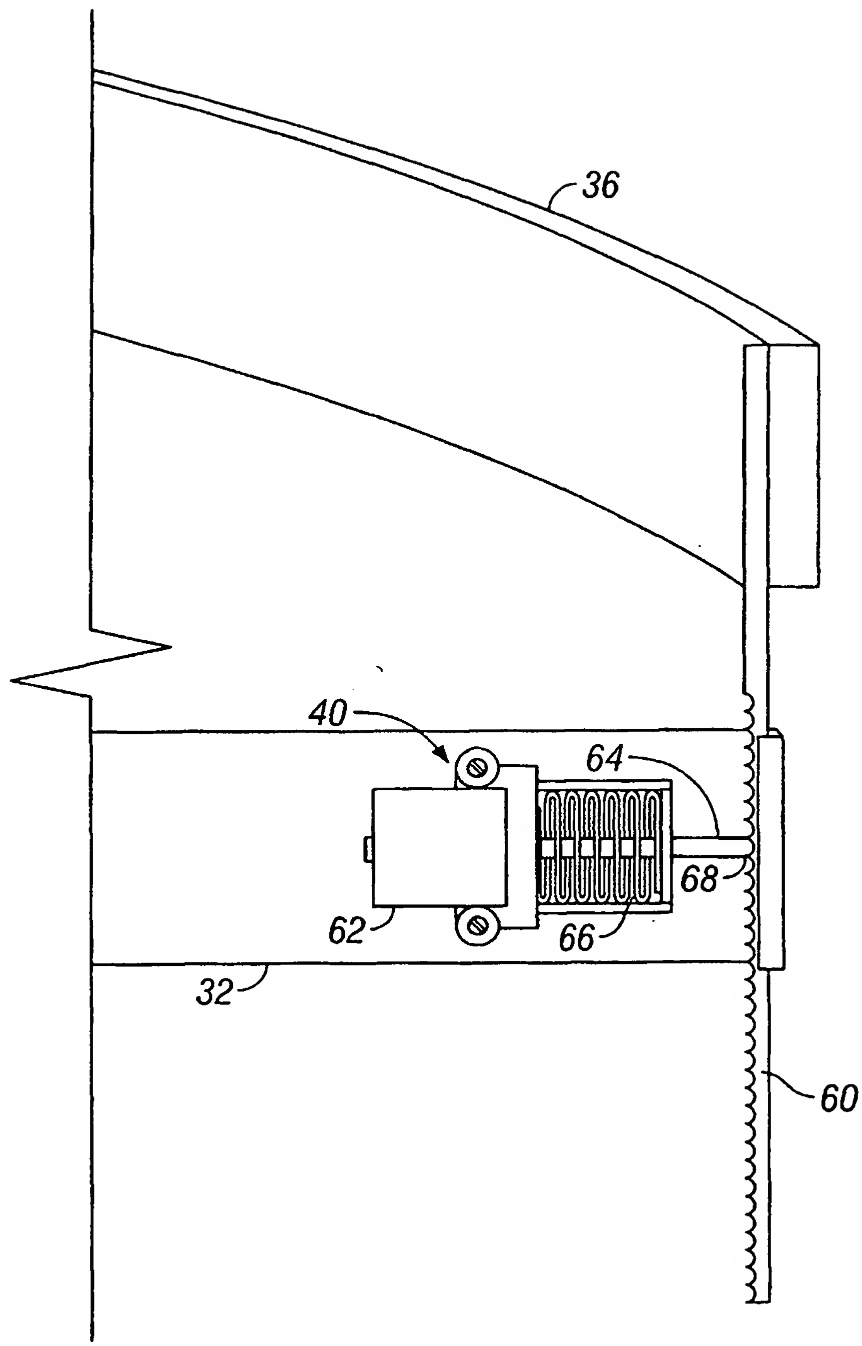

FIG. 2

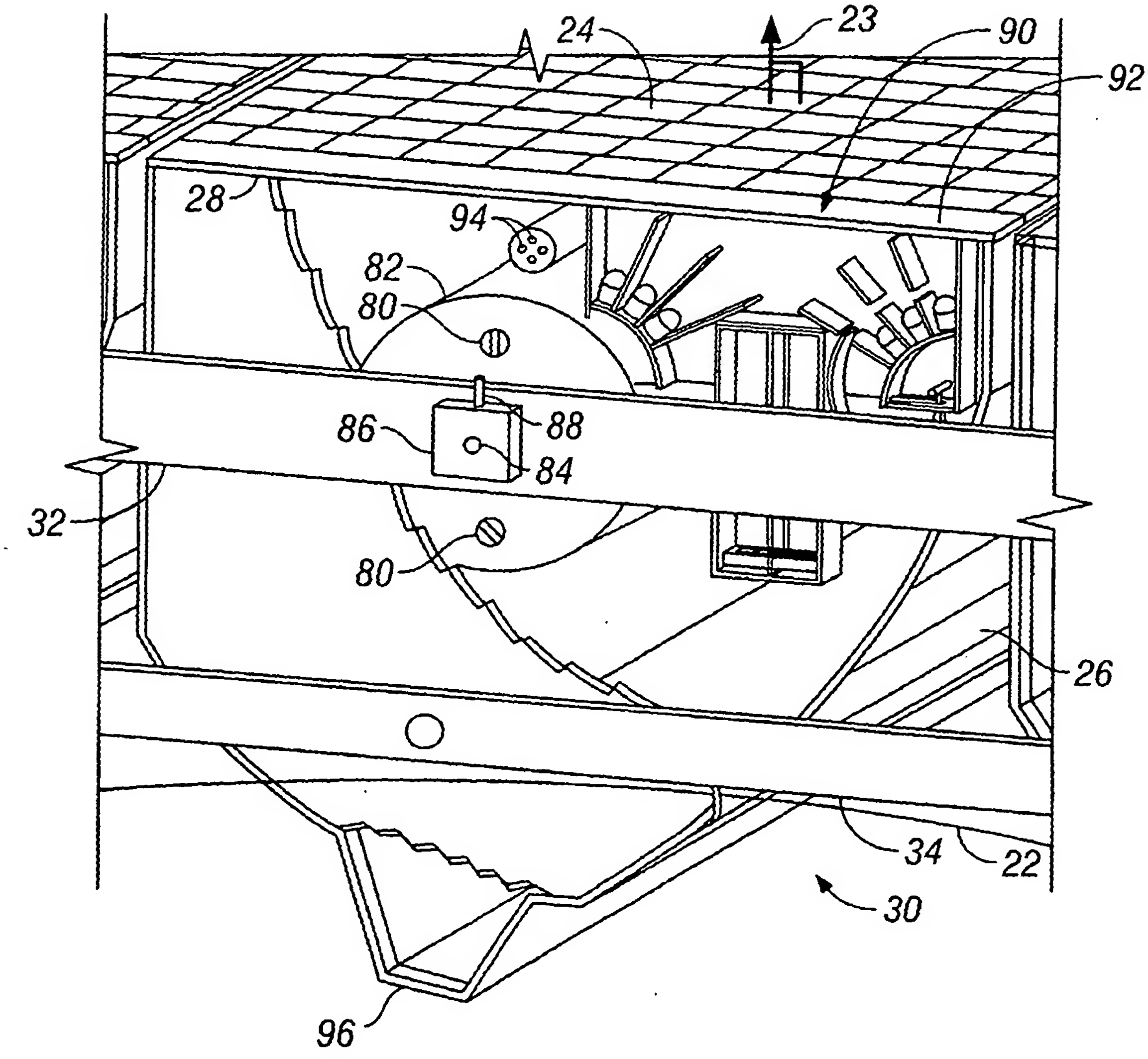

FIG. 3

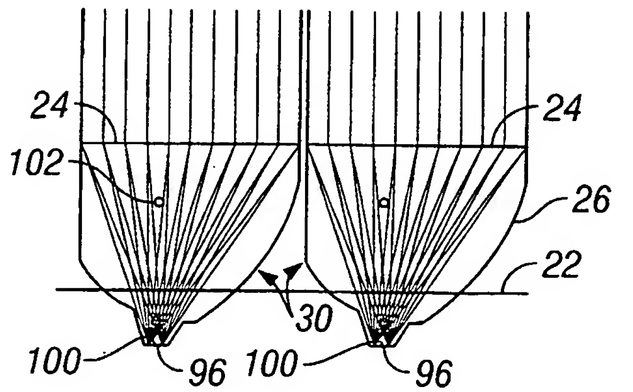

FIG. 4

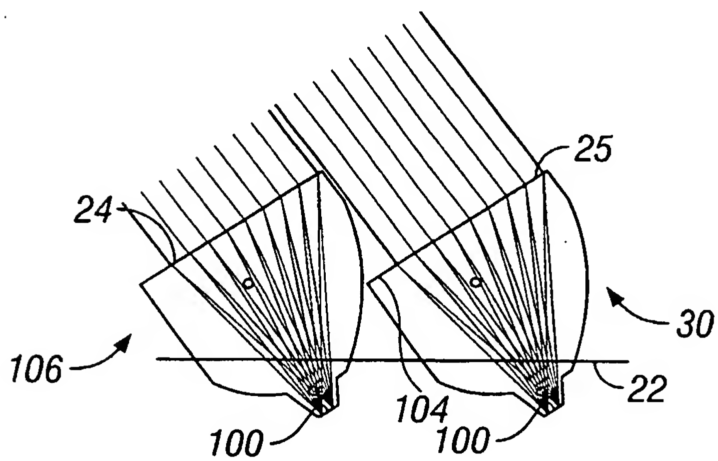

FIG. 5

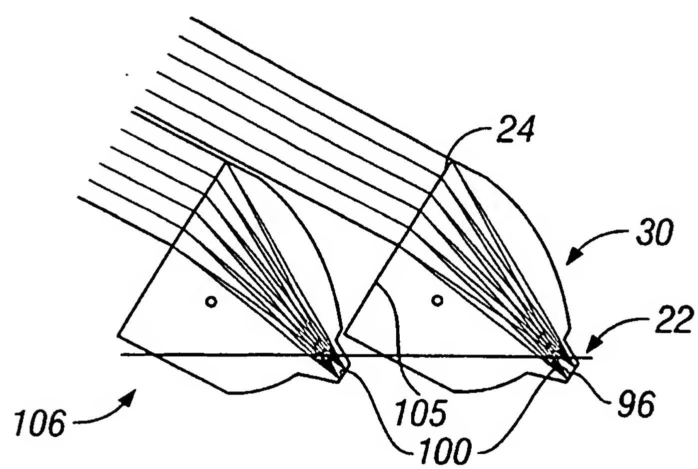

FIG. 6

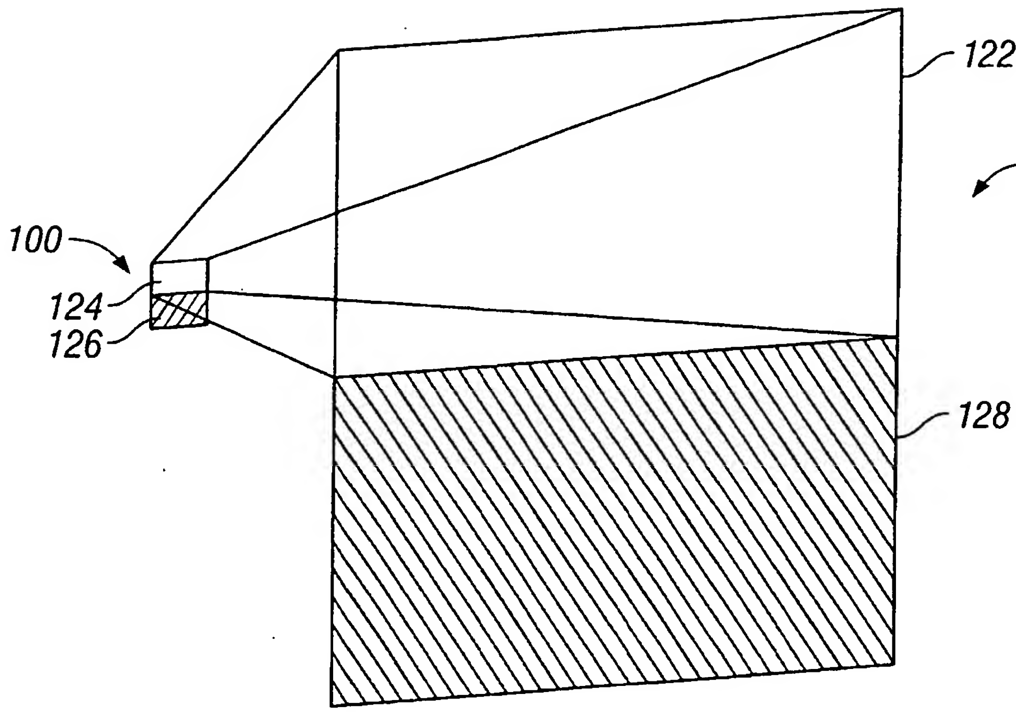
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FIG. 7

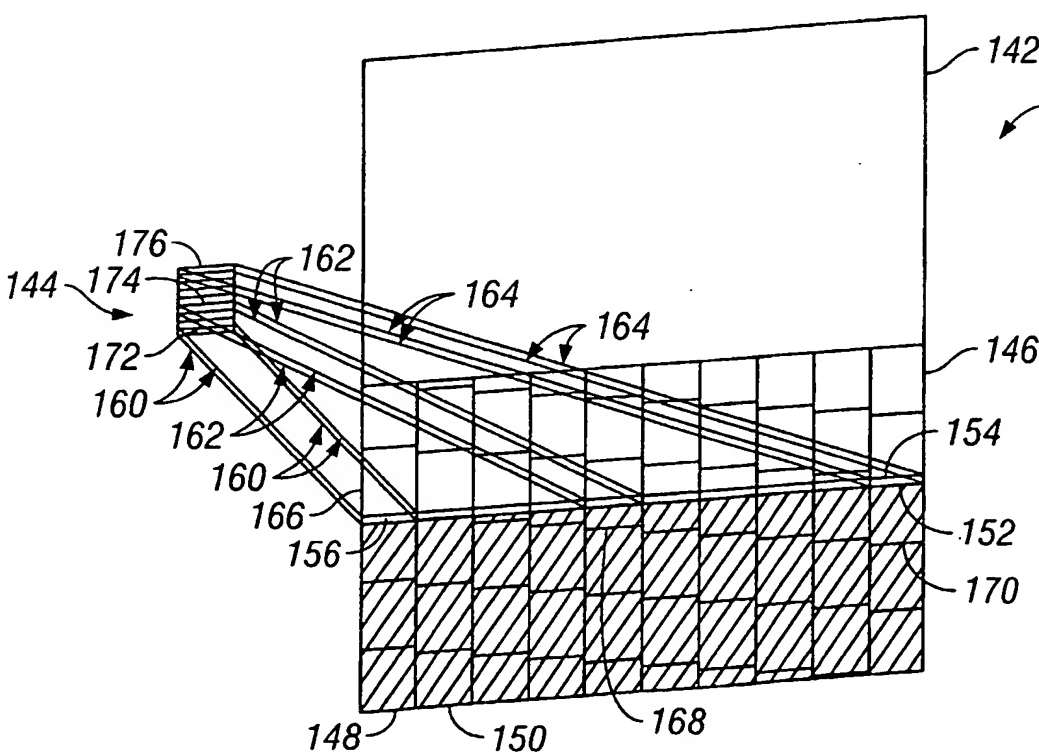
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FIG. 8

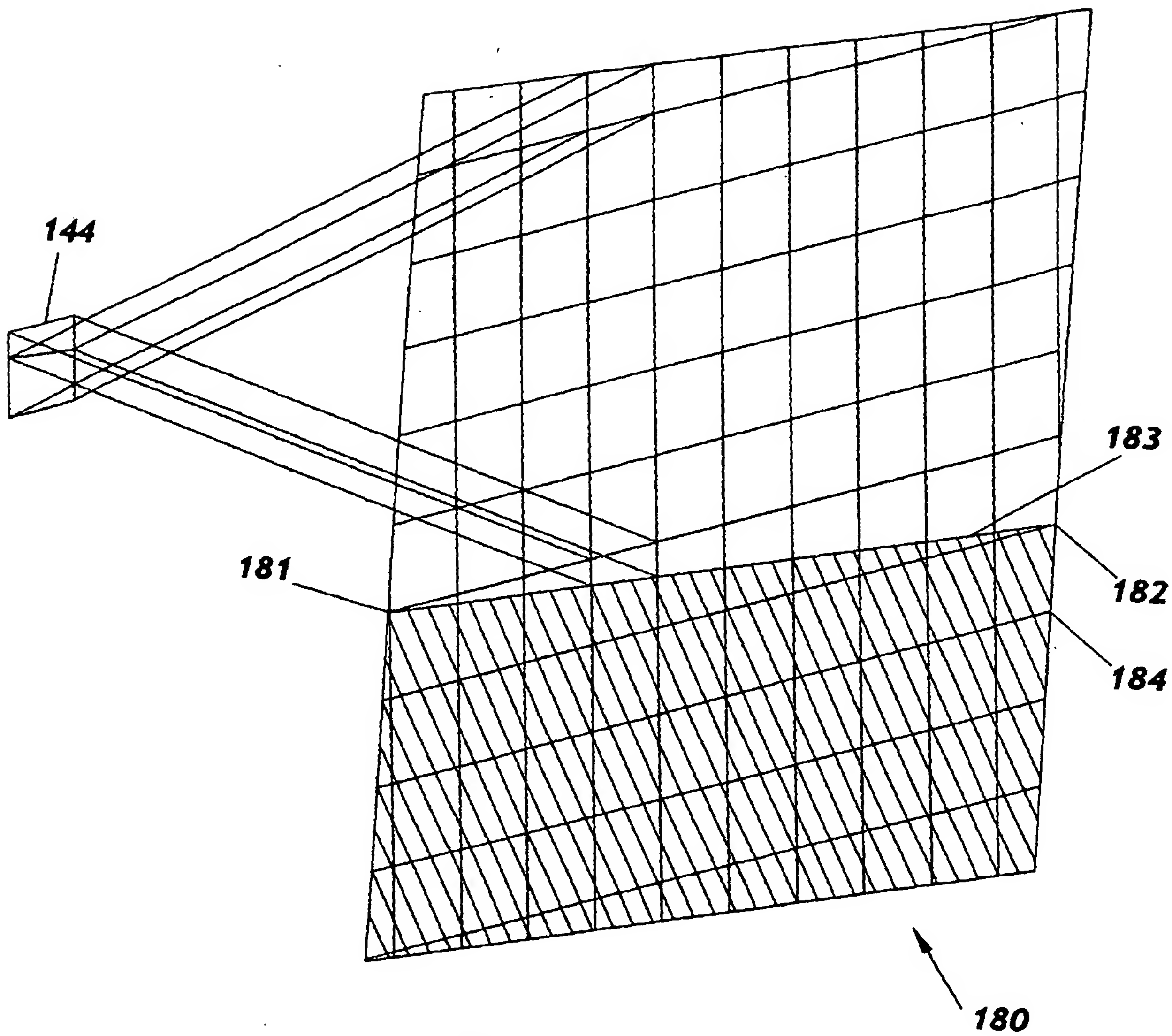

FIG. 9

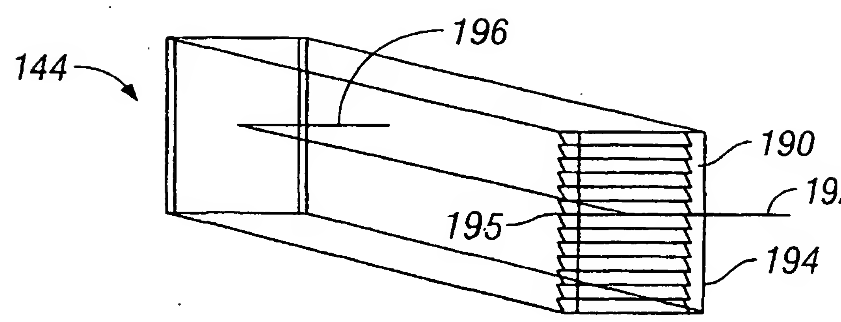

FIG. 10

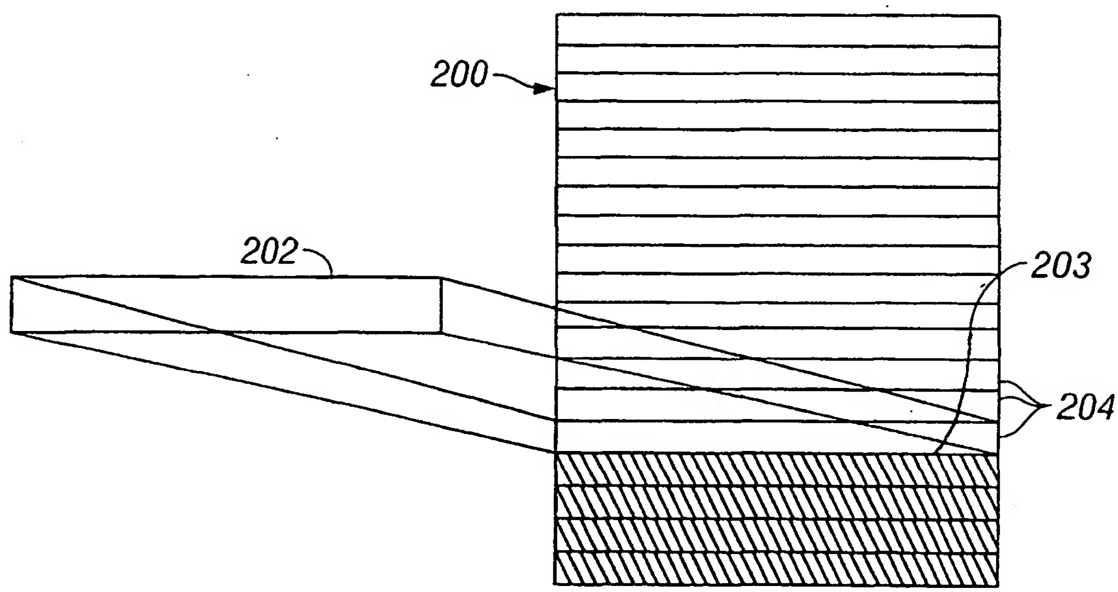

FIG. 11

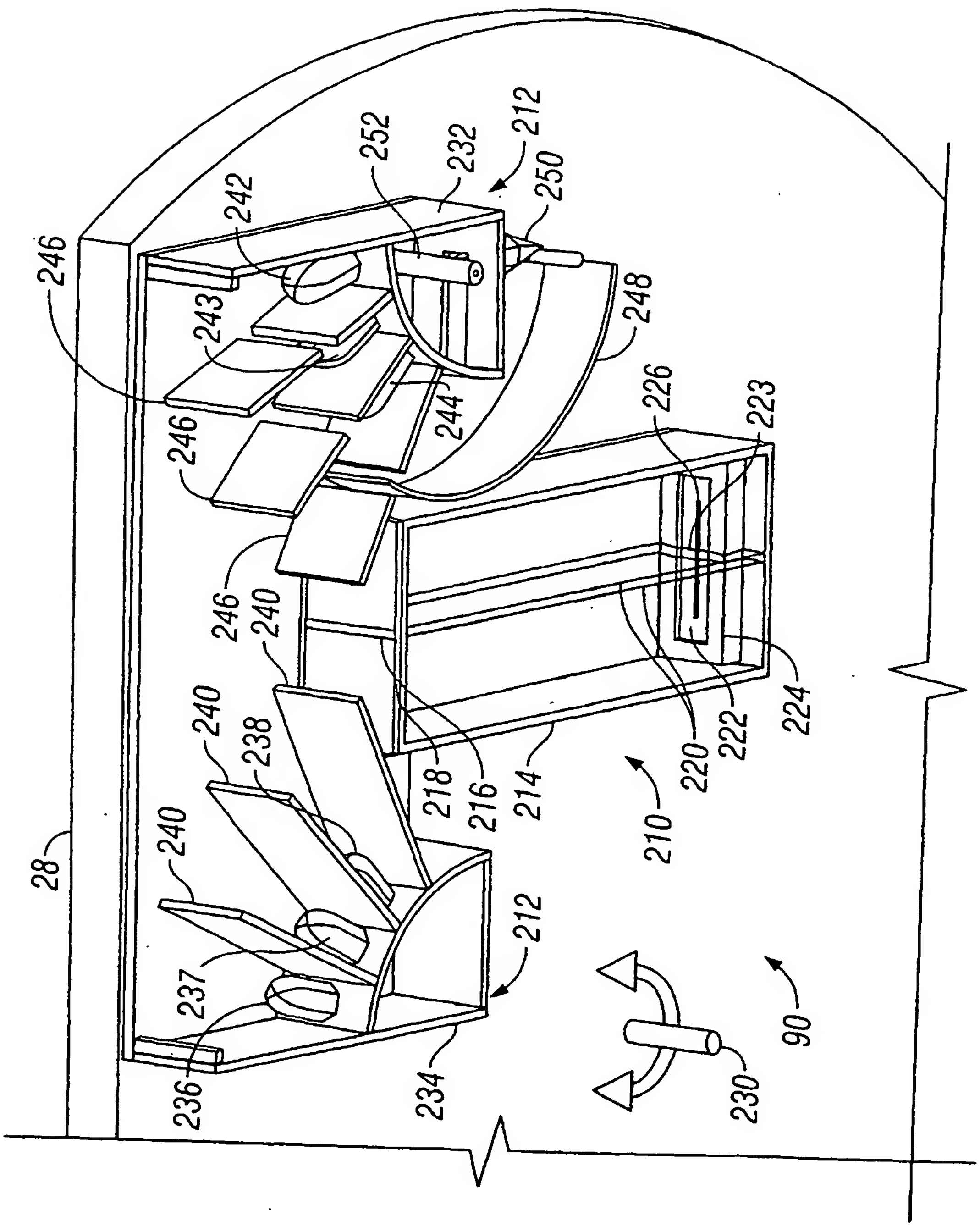
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FIG. 12

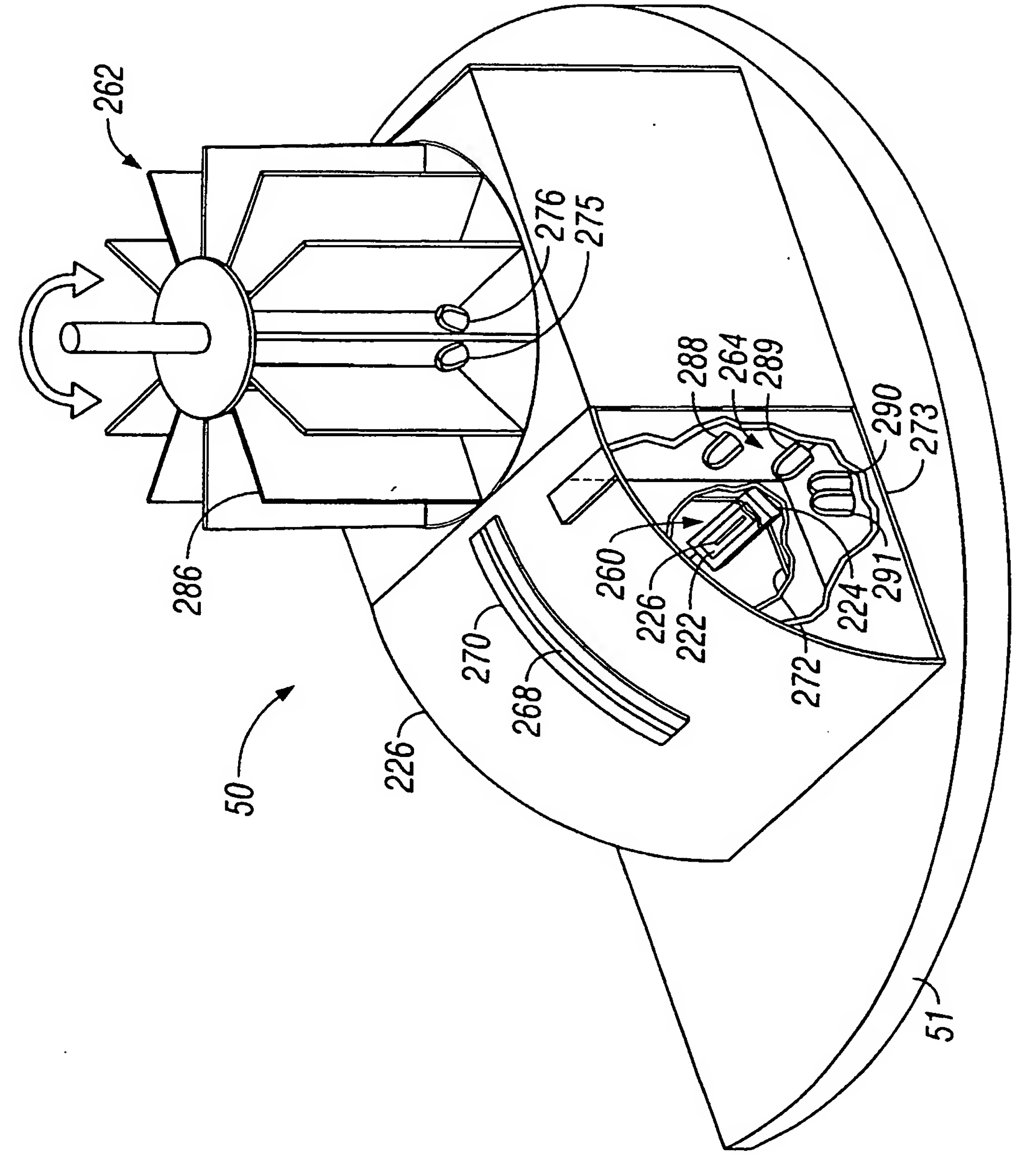
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FIG. 13

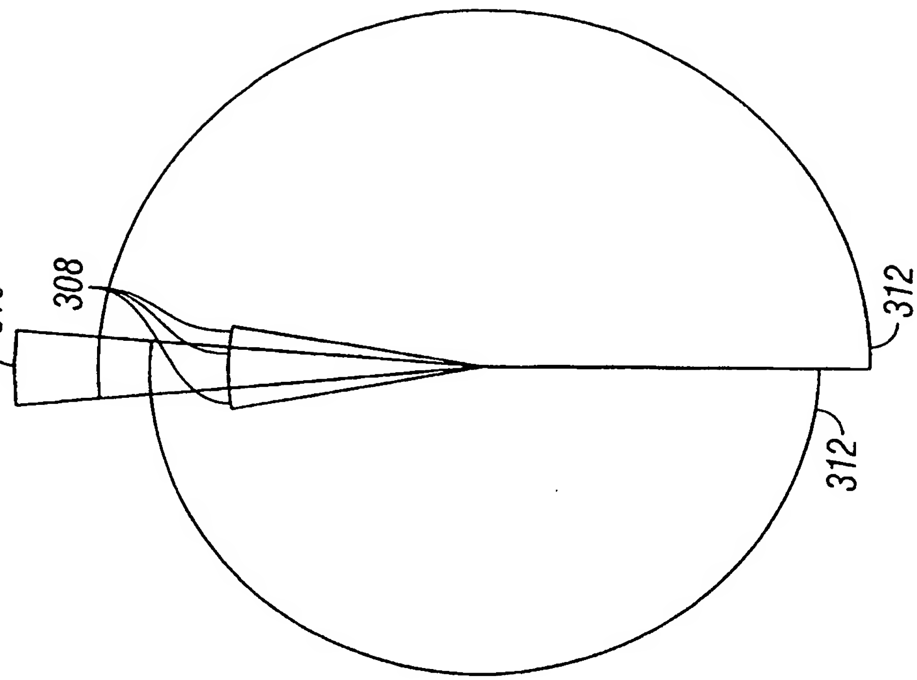


FIG. 15

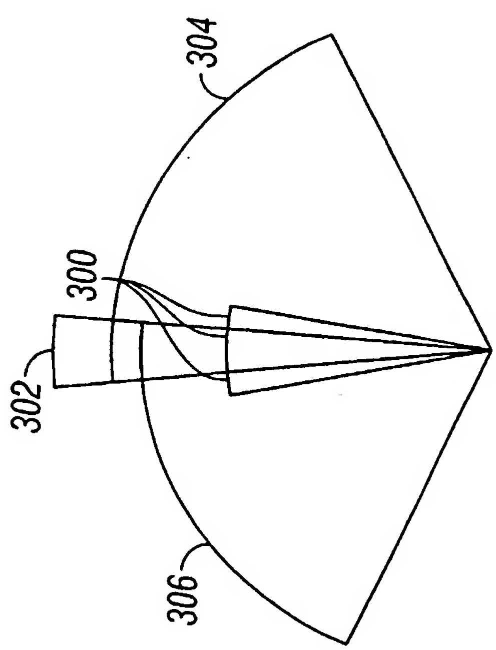
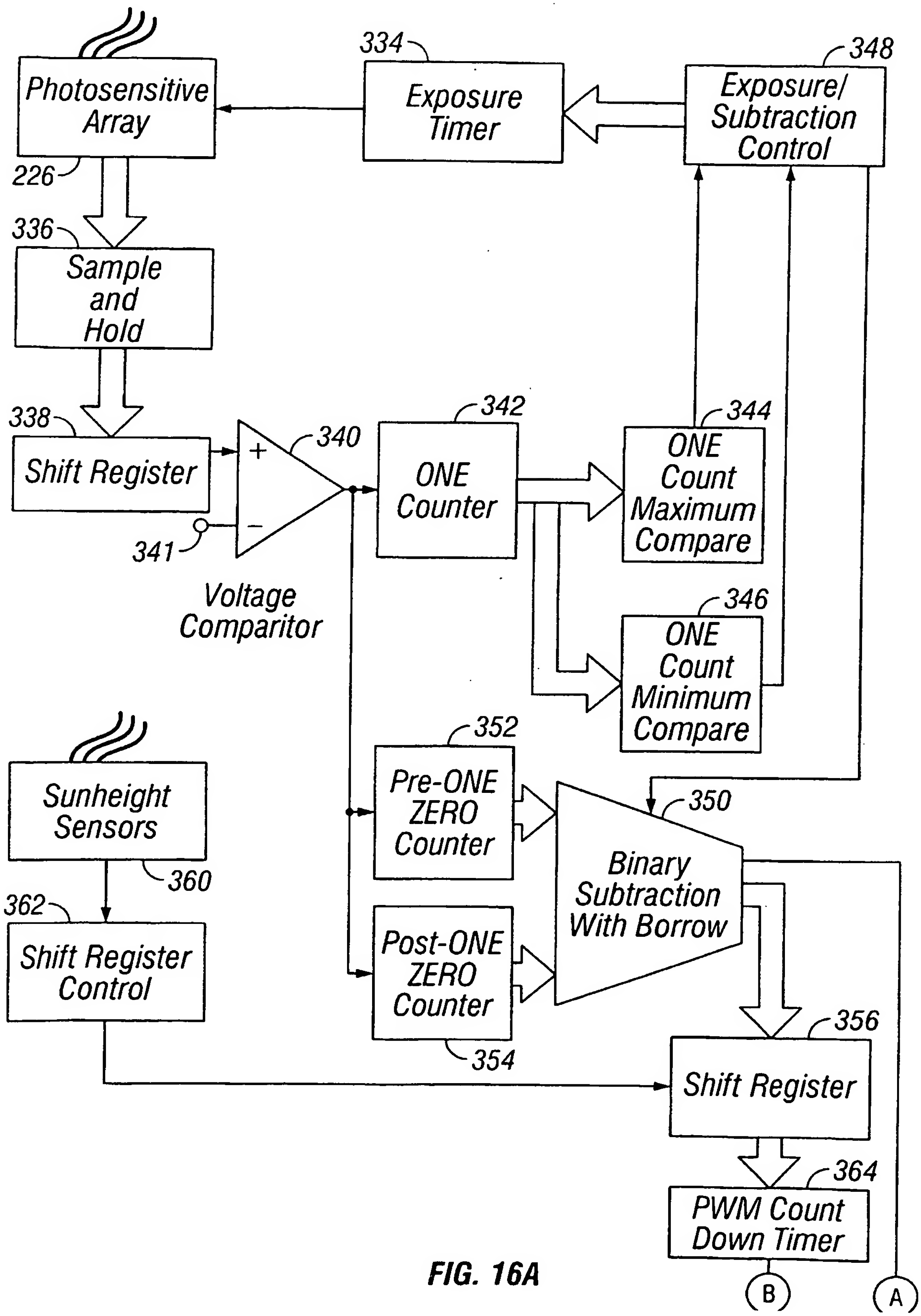
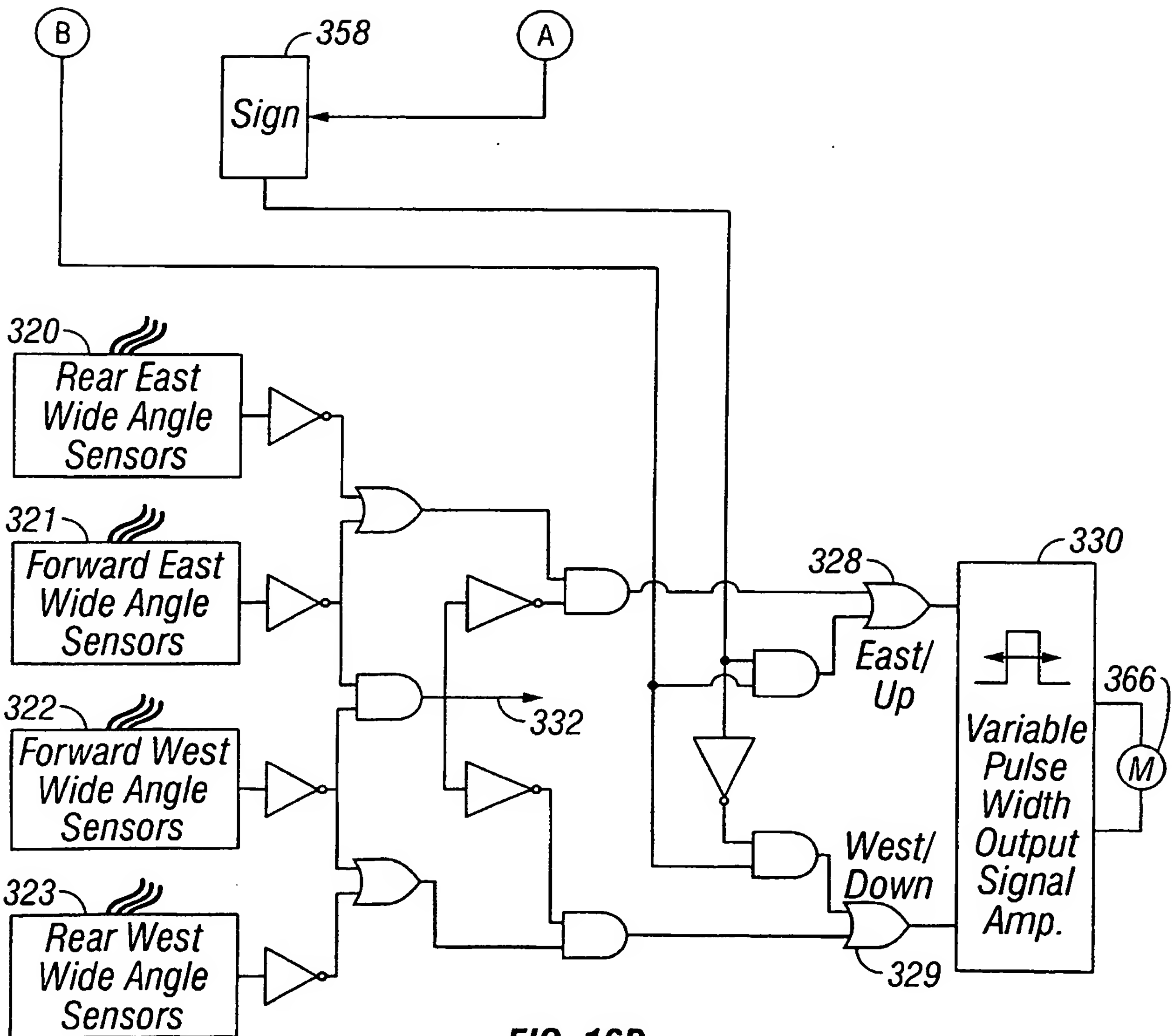


FIG. 14



Photosensitive Array
226
334
Exposure Timer
348
Exposure/ Subtraction Control
336
Sample and Hold
338
Shift Register
340
341
Voltage Comparitor
342
ONE Counter
344
ONE Count Maximum Compare
346
ONE Count Minimum Compare
352
Pre-ONE ZERO Counter
354
Post-ONE ZERO Counter
350
Binary Subtraction With Borrow
Sunheight Sensors
360
362
Shift Register Control
356
Shift Register
364
PWM Count Down Timer
B
A

FIG. 16A



B
358
A
Sign
320
Rear East Wide Angle Sensors
321
Forward East Wide Angle Sensors
322
Forward West Wide Angle Sensors
323
Rear West Wide Angle Sensors
332
328
East/ Up
West/ Down
329
330
Variable Pulse Width Output Signal Amp.
366
M

FIG. 16B

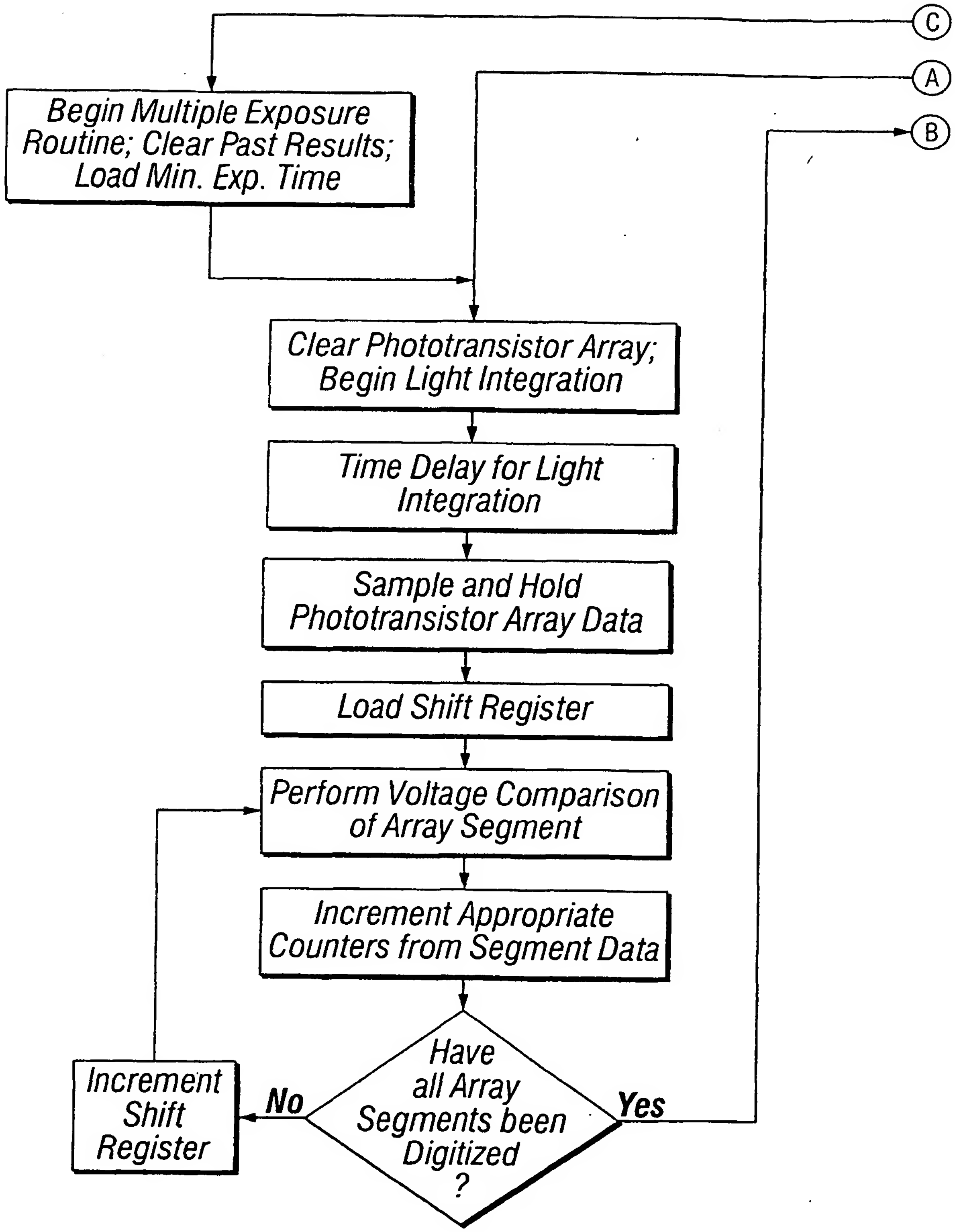

C
A
B
Begin Multiple Exposure Routine; Clear Past Results; Load Min. Exp. Time
Clear Phototransistor Array; Begin Light Integration
Time Delay for Light Integration
Sample and Hold Phototransistor Array Data
Load Shift Register
Perform Voltage Comparison of Array Segment
Increment Appropriate Counters from Segment Data
Have all Array Segments been Digitized ?
No
Yes
Increment Shift Register

FIG. 17A

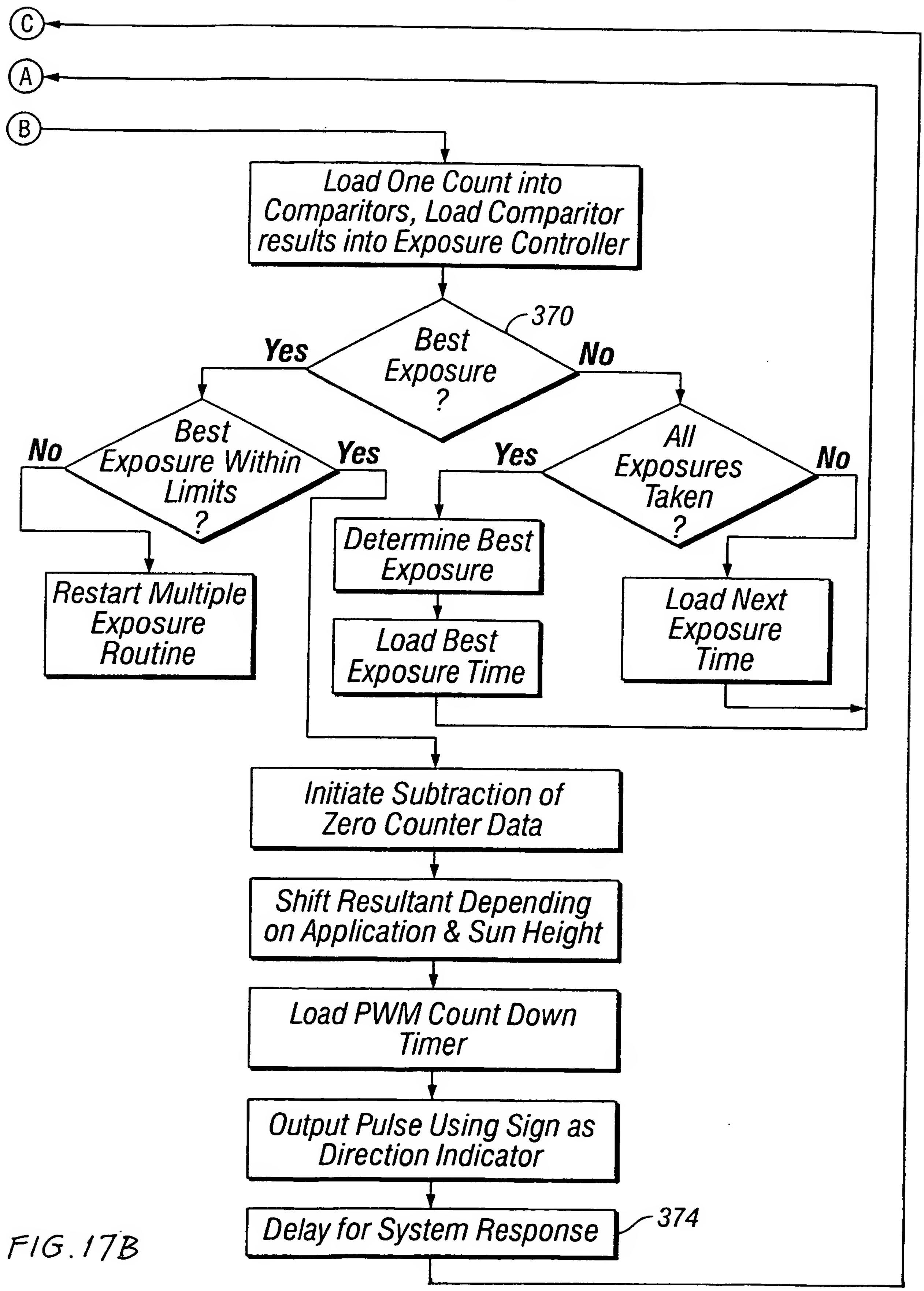
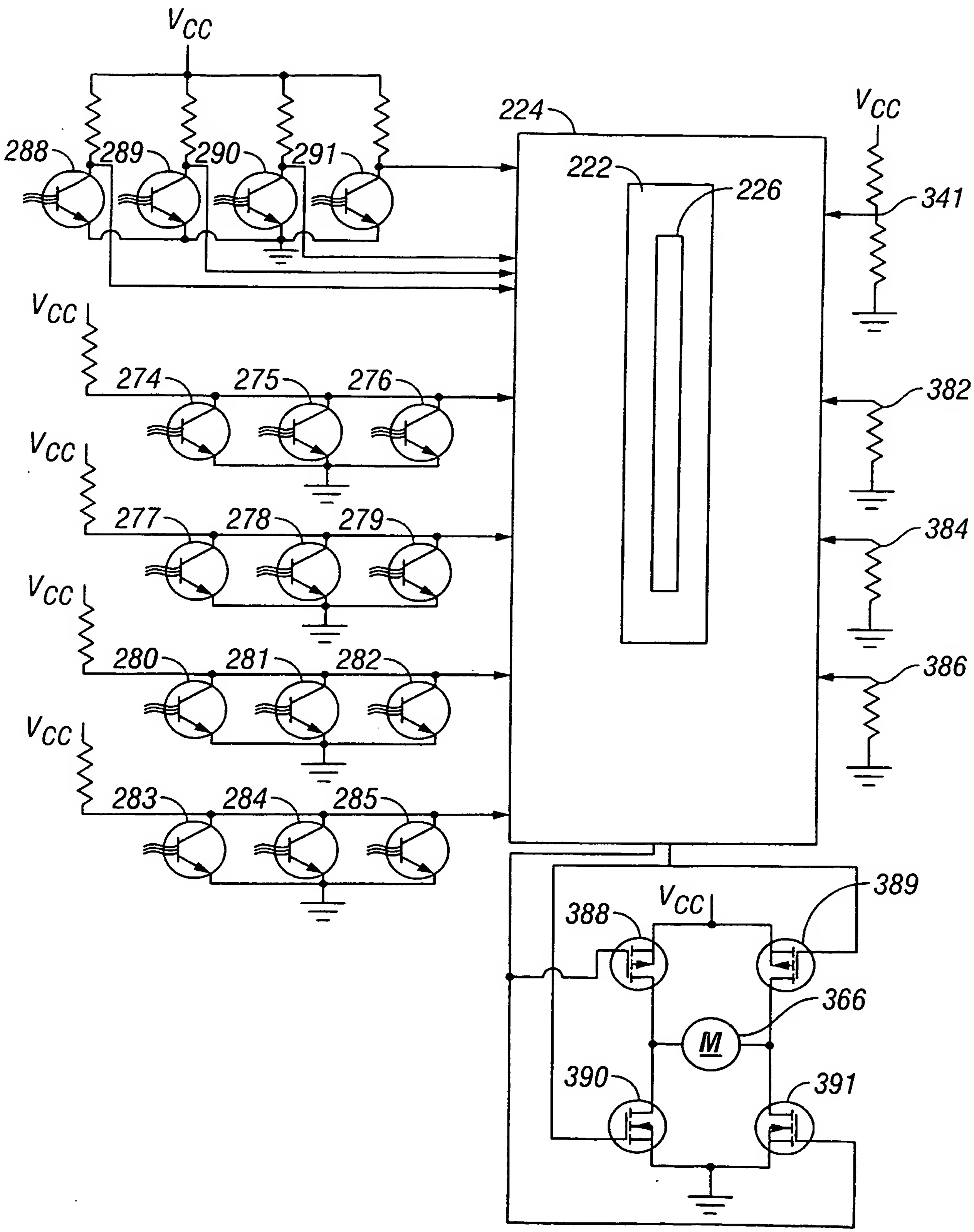

C
A
B
Load One Count into Comparitors, Load Comparitor results into Exposure Controller
370
Best Exposure ?
Yes
No
Best Exposure Within Limits ?
No
Yes
Yes
All Exposures Taken ?
No
Restart Multiple Exposure Routine
Determine Best Exposure
Load Best Exposure Time
Load Next Exposure Time
Initiate Subtraction of Zero Counter Data
Shift Resultant Depending on Application & Sun Height
Load PWM Count Down Timer
Output Pulse Using Sign as Direction Indicator
Delay for System Response
374

FIG. 17B



V_{CC}
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V_{CC}
V_{CC}
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279
384
V_{CC}
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FIG. 18

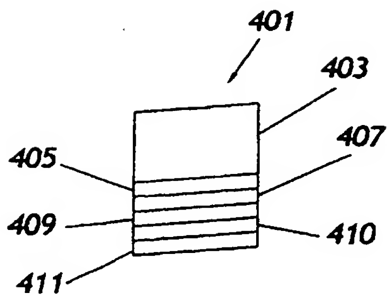

FIG. 19

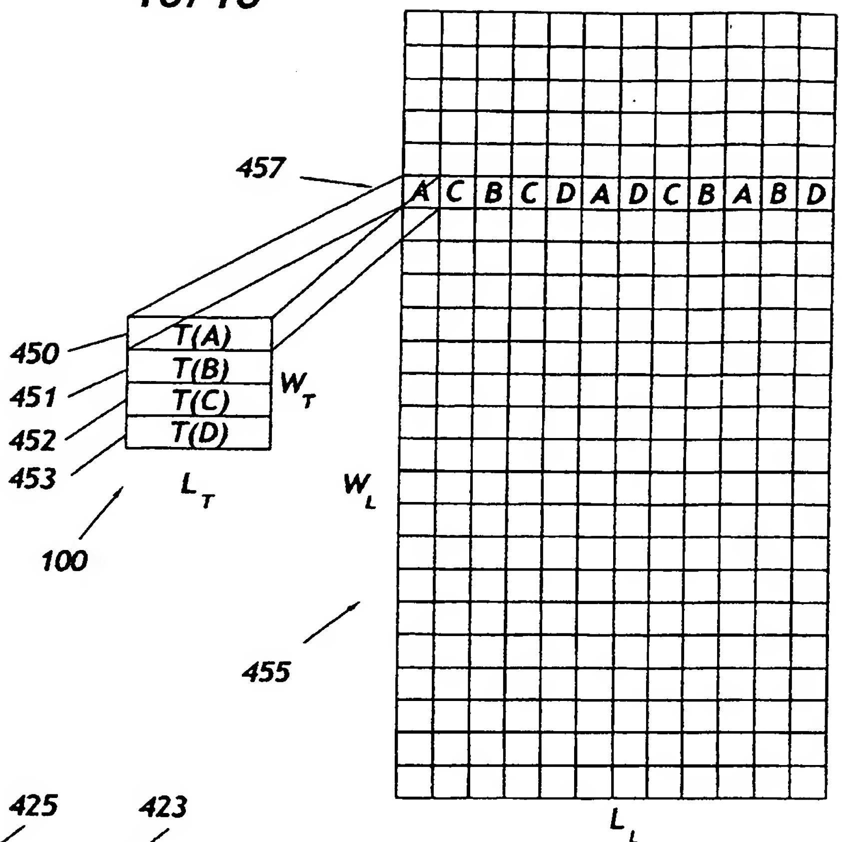

FIG. 21

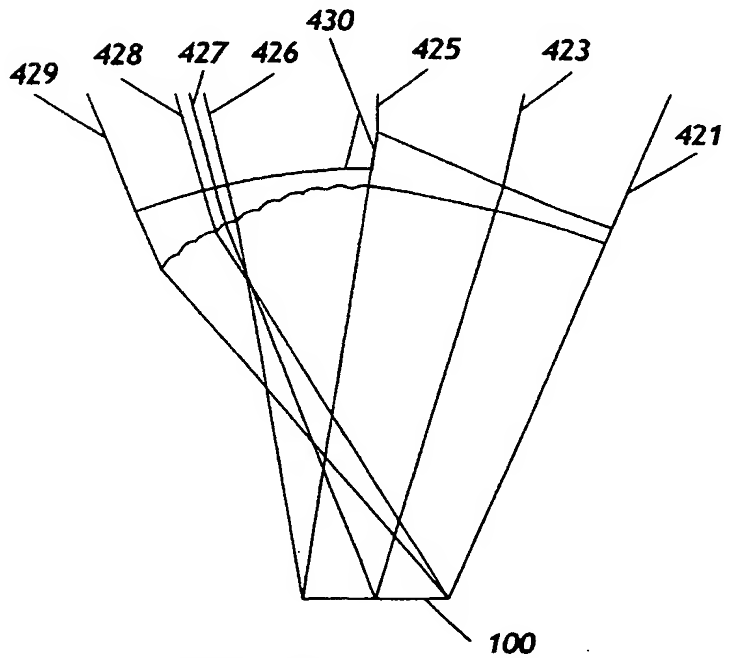

FIG. 20

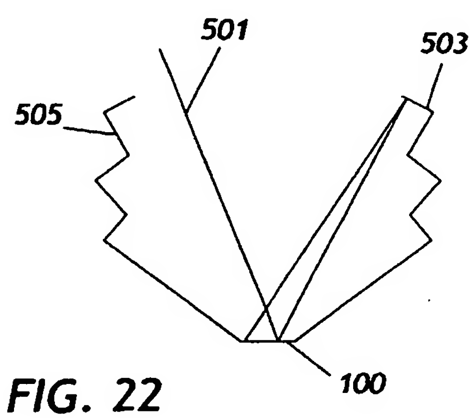

FIG. 22

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US02/32550

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : H01L 31/052; F24J 2/08; G02B 3/00, 3/08
US CL : 136/246; 126/698; 359/733, 741, 742
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 136/246; 126/698; 359/733, 741, 742

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,771,764 A (CLUFF) 20 September 1988 (20.09.1988), figures 1 and 7, and column 2, lines 44-60.	1-40
X	US 4,069,812 A (O'NEILL) 24 January 1978 (24.01.1978), figures 6-11.	41-70
X	US 4,204,881 A (MCGREW) 27 May 1980 (27.05.1980), figure 5.	41-70
X	US 4,496,787 A (TOUCHAIS et al) 29 January 1985 (29.01.1985), fiugre 1.	41-70
A	US 5,286,305 A (LAING et al) 15 February 1994 (15.02.1994).	1-70
A	US 5,445,177 A (LAING et al) 29 August 1995 (29.08.1995).	1-70
A	US 5,665,174 A (LAING et al) 09 September 1997 (09.09.1997).	1-70

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
23 December 2002 (23.12.2002)

Date of mailing of the international search report
14 JAN 2003

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231
Facsimile No. (703)305-3230

Authorized officer
Alan Diamond
Telephone No. 703-308-0661

Evidence Appdx 3

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:
WILLIAM C. BOLING
5656 HAMILL AVENUE
SAN DIEGO, CA 92120

PCT

WRITTEN OPINION

(PCT Rule 66)

Date of Mailing (*day/month/year*) 22 AUG 2003		
Applicant's or agent's file reference MORGAL 11	REPLY DUE within 2 months/days from the above date of mailing	
International application No. PCT/US02/32550	International filing date (*day/month/year*) 11 October 2002 (11.10.2002)	Priority date (*day/month/year*) 11 October 2001 (11.10.2001)
International Patent Classification (IPC) or both national classification and IPC IPC(7): H01L 31/052; F24J 2/08; G02B 3/00, 3/08 and US Cl.: 136/246; 126/698; 359/733, 741, 742		
Applicant MORGAL, RICHARD		

1. This written opinion is the first (first, etc,) drawn by this International Preliminary Examining Authority.
2. This opinion contains indications relating to the following items:

   - I ☒ Basis of the opinion
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Rule 66.2 (a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

3. The applicant is hereby **invited to reply** to this opinion.

   When? See the time limit indicated above. ~~The applicant may, before the expiration of that time limit, request this Authority to grant an extension. See rule 66.2(d).~~

   How? By submitting a written reply, accompanied, where appropriate, by amendments, according to Rule 66.3. For the form and the language of the amendments, see Rules 66.8 and 66.9.

   Also For an additional opportunity to submit amendments, see Rule 66.4.
   For the examiner's obligation to consider amendments and/or arguments, see Rule 66.4 *bis*.
   For an informal communication with the examiner, see Rule 66.6

   If no reply is filed, the international preliminary examination report will be established on the basis of this opinion.

4. The final date by which the international preliminary examination report must be established according to Rule 69.2 is: 11 February 2004 (11.02.2004).

Name and mailing address of the IPEA/US Mail Stop PCT, Attn: IPEA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (703)305-3230	Authorized officer Alan Diamond Telephone No. 703-308-0661

Form PCT/IPEA/408 (cover sheet)(July 1998)

WRITTEN OPINION

International application No.
PCT/US02/32550

I. Basis of the opinion

1. With regard to the **elements** of the international application:*

☒ the international application as originally filed

☒ the description:
pages 1-21, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of ______.

☒ the claims:
pages 22-28, as originally filed
pages NONE, as amended (together with any statement) under Article 19
pages NONE, filed with the demand
pages NONE, filed with the letter of ______.

☒ the drawings:
pages 1-16, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of ______.

☐ the sequence listing part of the description:
pages NONE, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of ______.

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language ______ which is:

☐ the language of a translation furnished for the purposes of international search (under Rule23.1(b)).
☐ the language of publication of the international application (under Rule 48.3(b)).
☐ the language of the translation furnished for the purposes of international preliminary examination(under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the written opinion was drawn on the basis of the sequence listing:

☐ contained in the international application in printed form.
☐ filed together with the international application in computer readable form.
☐ furnished subsequently to this Authority in written form.
☐ furnished subsequently to this Authority in computer readable form.
☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☐ The amendments have resulted in the cancellation of:

☐ the description, pages NONE
☐ the claims, Nos. NONE
☐ the drawings, sheets/~~fig~~ NONE

5. ☐ This opinion has been drawn as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this opinion as "originally filed."*

WRITTEN OPINION	International application No. PCT/US02/32550

V. Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. STATEMENT

Novelty (N)	Claims	NONE	YES
	Claims	1-70	NO
Inventive Step (IS)	Claims	NONE	YES
	Claims	1-70	NO
Industrial Applicability (IA)	Claims	1-70	YES
	Claims	NONE	NO

2. CITATIONS AND EXPLANATIONS

Claims 1-40 lack novelty under PCT Article 33(2) as being anticipated by Cluff, U.S. Patent 4,771,764. Cluff teaches a water-borne azimuth-altitude tracking solar concentrator and converting system employing multiple lens collectors for redirecting sunlight for concentration on photovoltaic cells (see Figure 1; and col. 1, line 50 through col. 2, line 28). A floating platform (32) tracks the sun and is moved azimuthally each day (see col. 3, lines 34-51). In particular, the platform is rotated, and solar panels (40) can be elevated, as seen in Figure 7 (see also col. 3, lines 52-60; and col. 6, lines 11-29). Since Cluff teaches the limitations of the instant claims, the reference is deemed to be anticipatory.

Claims 41-70 lack novelty under PCT Article 33(2) as being anticipated by Touchais et al, U.S. Patent 4,496,787. As seen in Figure 1, each subregion of Touchais et al's lens is configured to distribute light substantially uniformly toward the target. Since Touchais et al teaches the limitations of the instant claims, the reference is deemed to be anticipatory.

Claims 41-70 lack novelty under PCT Article 33(2) as being anticipated by McGrew, U.S. Patent 4,204,881. As seen in Figure 1, each subregion of McGrew's lens is configured to distribute light substantially uniformly toward the target. Since McGrew teaches the limitations of the instant claims, the reference is deemed to be anticipatory.

Claims 41-70 lack novelty under PCT Article 33(2) as being anticipated by O'Neill, U.S. Patent 4,069,812. As seen in Figures 6-11, each subregion of O'Neill's lens is configured to distribute light substantially uniformly toward the target. Since O'Neill teaches the limitations of the instant claims, the reference is deemed to be anticipatory.

Claims 1-70 meet the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.

WRITTEN OPINION

International application No.
PCT/US02/32550

Supplemental Box
(To be used when the space in any of the preceding boxes is not sufficient)

TIME LIMIT:
The time limit set for response to a Written Opinion may not be extended. 37 CFR 1.484(d). Any response received after the expiration of the time limit set in the Written Opinion will not be considered in preparing the International Preliminary Examination Report.

Evidence Appdx 4

PATENT / PCT

Date: 22 October 2003

COMMUNICATION TO THE IPEA/US

In Re International Application of: **Morgal**

Serial No.: **PCT/US02/32550**

Filed: **11 October 2002**

Title: **Method And Apparatus for Solar Energy Collection**

Examiner: **Alan Diamond**

EU 778103625 US

Certification under 37 CFR 1.10

I hereby certify that the correspondence attached hereto is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service pursuant to 37 CFR 1.10, addressed to Mail Stop PCT, Attn: IPEA/US, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, Express Mail No. **EU778103625US**, on 22 October 2003.

22.11.2003 William C. Boling

Date William C. Boling

Mail Stop PCT, Attn: IPEA/US
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

REPLY TO WRITTEN OPINION

Dear Sir:

This is a reply to a Written Opinion (hereafter "the Written Opinion") that was mailed on 22 August 2003 in respect of the above-identified international application. The Examiner is respectfully requested to consider the remarks set forth below prior to issuing an International Preliminary Examination Report in respect of the subject application.

REMARKS

Objection to Claims 1-40 As Lacking Novelty Over Cluff

In subsection 2 of Section V of the Written Opinion, the Examiner asserts that Claims 1-40 are anticipated by U.S. Patent 4,771,764 to Cluff ("Cluff").

Claim 2 recites in part (underlining added for emphasis):

> (d) the liquid bath is a coolant that provides primary cooling of the conversion device through thermal contact with an exterior of the support structure.

Cluff does not disclose, teach or suggest the limitations required by Claim 2. Instead, Cluff teaches the use of "a liquid" that is forced through channels in the support structure (see column 5, lines 30-45), which does not constitute cooling "through thermal contact with an exterior of the support structure," as required by Claim 2. With respect to the floating structures of Cluff, the disclosed structure is a hollow U-tube that is incompatible with cooling "through thermal contact with an exterior," as required (See Figure 15 and column 6 lines 64-67 of Cluff).

Claim 3 recites in part (underlining added for emphasis):

> (d) the support structure is a first support structure, and is disposed in contact with a liquid bath in an array of support structures, substantially abutting adjacent support structures that each have an elevation rotation axis parallel to and in a plane with the elevation rotation axis of the first support structure.

Cluff does not disclose, teach or suggest the limitations required by Claim 3. To the contrary, Cluff teaches directly away from the limitations conveyed by the underlined text. Cluff states (bold type added for emphasis): "As shown in FIG. 13, the panels 65 **must** be spacedly arranged with **enough open space therebetween** so that the panels may be moved to and from a horizontal position **without touching** a juxtapositioned panel." The teaching of Cluff imposes a very significant area-utilization penalty, by precluding the abutment of adjacent structures. The invention of the Applicant, as defined in Claim 3, overcomes this utilization penalty. Cluff fails to teach the Applicant's invention, as recited in Claim 3, and indeed teaches directly away from limitations recited in Claim 3.

Claim 4 recites in part (underlining added for emphasis):

> (d) light parallel to the incoming light axis that enters with uniform density across an entire surface of the lens exits the lens at angles with respect to the incoming light axis, with the average of all such exiting light angles defining a light delivery axis, and the light delivery axis has a significant non-zero angle with respect to the incoming light axis.

Cluff does not teach, disclose or suggest these limitations. Cluff has no explicit teaching in this regard, but each example of lens concentration in Cluff implies a zero angle (on average) between the incoming light axis and the light delivery axis (see Figures 2, 5 and 15 of Cluff). The non-zero angle required by the Applicant's Claim 4 permits a useful support structure geometry. In particular, for example, the non-zero angle permits that portion of the support structure, upon which the photovoltaic is disposed, to be positioned to remain in contact with the liquid bath (and thus to be passively cooled) over a wider range of elevation angles than would be possible with a construction such as taught by Cluff. Because Cluff fails to teach, disclose or suggest these limitations, Cluff does not anticipate the invention claimed in Claim 4, and indeed does not render such invention obvious.

Claim 5 recites in part (underlining added for emphasis):

> (d) the receiving region of the lens is subject to shadowing that causes substantially non-uniform illumination of the receiving region of the lens, and the lens cooperates with the one or more converter devices to avoid substantially non-uniform illumination of operating photovoltaic conversion devices due to such shadowing.

Cluff does not consider or address the issue of shadowing at all. As such, Cluff entirely fails to teach, disclose or suggest any cooperation between a lens and a converter device to avoid non-uniform illumination during such shadowing. Thus, Cluff fails to anticipate, or to render obvious, Claim 5.

Claim 7 recites in part (underlining added for emphasis):

> (d) the support structure floats in a coolant bath that has an average surface plane, and the photovoltaic converter devices are mounted on corresponding portions of

> the support structure that are <u>below the coolant bath</u> average surface plane <u>for all light source elevation angles</u> within 45 degrees from vertical.

Cluff makes no relevant suggestions whatsoever in regard to a position of the converter device with respect to the coolant bath. Indeed, Cluff does not even teach a "coolant bath," but rather (as noted above with respect to Claim 2) teaches a cooling liquid forced through the support structure. Thus, Cluff also fails to teach, disclose or suggest the limitations recited in Claim 7, and as such fails to anticipate, or render obvious, Claim 7.

It is thus respectfully submitted that Cluff fails to anticipate, or to render obvious, any of Claims 2-5 and 7. Claims 6 and 8-21 each contain all of the limitations of at least one of Claims 2-5 and 7, by virtue of dependency. As such, it is respectfully submitted that each of Claims 2-21 are novel, and involve an inventive step, as compared to Cluff.

Cluff fails to anticipate, or render obvious, the Applicant's Claims 23, 24, 25 and 26 for reasons substantially similar to those set forth above with respect to Claims 2, 3, 4 and 5, respectively. Cluff fails to anticipate, or render obvious, the Applicant's Claims 27 and 28 for reasons substantially similar to those set forth above with respect to Claim 7.

Each of Claims 29-40 include all of the limitations of at least one of Claims 23-28 by virtue of dependency. It is therefore respectfully submitted that Cluff fails to anticipate, or to render obvious, any of the Applicant's Claims 2-21 or 23-40.

Objection to Claims 41-70 As Lacking Novelty Over Touchais, McGrew, or O'Neill

Before considering the teaching of the cited references, it will be useful to consider some of the limitations that are present in each of Claims 41-70. Each of these claims includes all of the limitations of one of the independent claims Claim 41 or Claim 61. Accordingly, the Examiner's attention is directed to some of the limitations set forth in these claims. Independent Claim 41 recites in part (underlining added for emphasis):

> c) each subregion is configured to <u>distribute light substantially uniformly</u> toward the target.

In a generally similar manner, independent Claim 61 recites in part (underlining added for emphasis):

b) configuring a plurality of light-receiving subregions of the overall region to each individually <u>distribute light uniformly toward substantially an entirety of the target</u>.

These limitations, requiring uniformity of light distribution toward the target by each of a plurality of subregions, are similar enough that the same remarks will apply to both. In Claim 41, "the target" is "an energy collection target." In accordance with the Applicant's specification, and with the physics of solar energy collection, a target that is a single point could not collect solar energy. Consequently, a solar energy collection target necessarily has a finite area. Indeed, "uniform distribution" would be nonsensical if the target were a mere point. Claim 61 employs somewhat different language, reciting "toward substantially an entirety of the target." However, substantial uniformity of light distribution toward a target (of finite size), by each of a plurality of subregions, is required by both Claim 41 and Claim 61.

The distribution of light (solar energy) directed toward a solar energy collection target may not generally be assumed to be uniform. In the absence of special attention to design, lenses will tend to focus light more intensely on one portion of a target than on another, even when nominally directing light toward the target. In particular, lenses are typically designed to have a "point focus," and light will be distributed more intensely near such point focus.

Certain types of concentrating photovoltaic converters may suffer significant losses of efficiency when they are illuminated unevenly, or non-uniformly. Therefore, the features required by Claims 41 and 61, in regard to uniform distribution of light toward the target, have particular value in conjunction with such concentrating solar photovoltaic converters. Moreover, providing such distribution from a plurality of subregions of a lens may help avoid uneven illumination of the target when the lens is partially shaded. Benefits may also accrue from these features when used with other types of converters, and accordingly the invention need not be limited to photovoltaic energy conversion.

However, incident light distribution uniformity may matter less to solar energy collection techniques that are based upon heat exchange. Many existing solar energy conversion techniques merely involve converting the incident solar radiation to heat energy, and then conveying the heat energy elsewhere for further processing or storage.

Heat exchange techniques are not generally sensitive to a distribution of incoming energy. Rather, heat exchange generally requires only that the incident radiation be absorbed by some portion of a heat exchange target. As such, designers of thermal solar energy converters are unlikely to perceive a benefit that would justify an effort to effect a uniform distribution of light toward a target. The greater design difficulty of requiring uniform distribution from each of a plurality of lens subregions is therefore likely to be seen as even less warranted, for systems that primarily collect solar energy by means of heat exchange.

In the Written Opinion, the Examiner rejects Claims 41-70 as being anticipated by U.S. Patent 4,496,787 to Touchais, et al. ("Touchais"). Touchais describes a Fresnel lens, which may fairly be said to comprise a "plurality of subregions" of the overall lens. However, Touchais makes no statement whatsoever in regard to the uniformity of light distributed toward the target from such subregions. Rather, Touchais merely suggests that the subregions focus the incoming light to a common focal point, which is entirely conventional (see, e.g., Figure 1 and column 1 lines 52-64 of Touchais).

As noted above, directing light to a focal point is generally contrary to distributing light uniformly toward a target of finite area. Touchais does not address the distribution of light, but a highly non-uniform distribution may be deduced because the target is a pipe (see item 5 of FIG. 1). Due to the curving (cylindrical) surface of the target, it would be virtually impossible for such a system to direct light uniformly toward the target.

The system described in Touchais converts solar energy into other forms of energy by means of heat transfer. As noted above, heat transfer systems are largely insensitive to the uniformity of distribution of incident light (solar energy) on a target, so long as the energy is absorbed somewhere by the target. Thus, the failure of Touchais to address the distribution uniformity of light (or solar energy) toward a target is expected, because designers of such systems are unlikely to expect a benefit to accrue from attention to uniform light distribution. Touchais does not even address the issue of uniform light distribution. Far less, then, does Touchais teach uniform light distribution toward a target by each of a plurality of subregions.

Because Touchais thus fails to teach, disclose or suggest all of the limitations of Claims 41 or 61, Touchais neither anticipates nor renders obvious these claims.

Furthermore, because each of Claims 42-60 and 62-70 comprise all of the limitations of either Claim 41 or Claim 61 by virtue of dependency, it is respectfully submitted that each of Claims 41-70 are novel and nonobvious over Touchais.

In the Written Opinion, the Examiner rejects Claims 41-70 as being anticipated by U.S. Patent 4,2004,881 to McGrew ("McGrew"). To support this rejection, the Examiner asserts that Figure 1 of McGrew illustrates a lens configured to distribute light substantially uniformly toward the target. With all due respect, Figure 1 does not illustrate <u>uniform</u> distribution of light to <u>the</u> target. To the contrary, Figure 1 of McGrew illustrates <u>distributing</u> light (according to spectral range) from a single subregion onto a <u>plurality</u> of targets. Thus, far from describing uniform distribution, McGrew teaches dispersing light from one subregion onto several different targets.

McGrew is concerned with the spectral content of light reaching the target, not the uniformity of the light. McGrew makes no suggestion whatsoever in regard to a uniformity of distribution. As such, it is respectfully submitted that McGrew fails to teach, disclose or suggest all of the limitations recited in either of the independent Claims 41 or 61, as set forth above. As such, McGrew can neither anticipate nor even render obvious either of these claims. Independent Claims 41 and 61 thus define an invention that is novel, and involves an inventive step, in view of the teaching of McGrew. Due to dependencies, then, it is respectfully submitted that McGrew fails to anticipate or render obvious any of Claims 41-70.

In the Written Opinion, the Examiner rejects Claims 41-70 as being anticipated by U.S. Patent 4,069,802 to O'neill ("O'neill"). O'neill is concerned with Fresnel lenses, and in particular with problems attendant on such lenses when used for solar energy collection. For example, O'neill, endeavors to minimize reflection losses by causing the incoming light angle to match the outgoing light angle (e.g., col. 2 lines 40-48, and col. 2 line 67 - col. 3 line 3), and to avoid one Fresnel prism from interfering with light from another Fresnel prism of the lens (e.g., col. 2 lines 48-55, and col. 3 lines 15-21). In regard to focus, however, O'neill teaches only that the light should be directed to a common focal area (col. 4, lines 8-13, and item 76 in Figures 1 and 2). O'neill does not discuss uniformity of light distribution. This omission is to be expected, because O'neill, like Touchais, primarily contemplates solar energy conversion by means of heat transfer (see, e.g., col. 4 lines 10-21). As noted above, such conversion techniques are generally

insensitive to light distribution uniformity, and thus a designer would not perceive a benefit to specially adjusting a uniformity of light directed to the target. Although O'neill mentions photovoltaic converters in passing (e.g., col. 14 lines 6-23), no suggestion is made in regard to a uniformity of the incident light directed toward the target. Thus, O'neill fails to anticipate or render obvious either Claim 41 or Claim 61.

It has been shown, above, that Touchais, McGrew and O'Neill each fail to teach or suggest a requirement of substantial uniformity of light distribution on the target. Even more so, then, these references all fail to disclose the limitations recited in independent Claims 41 and 61, which involve requiring such uniformity of distribution from each of a plurality of subregions. As such, none of these cited references is able to remedy the failure of any other of the cited references in this regard. Consequently, these three references individually fail to anticipate, or render obvious, either of independent Claims 41 or 61. As a further consequence, these references fail to establish a *prima facie* case of obviousness for either of independent Claims 41 or 61, even if they are combined.

Each of Claims 42-60 and 62-70 depend from either independent Claim 41 or independent Claim 61. It is therefore respectfully submitted that Touchais, McGrew, and O'neill, whether taken alone or combined together in any combination, fail to anticipate or render obvious any of Claims 41-70.

Conclusion

In view of the foregoing remarks, the Examiner is respectfully requested to reconsider the claims of the subject application with respect to the cited prior art, and to issue a favorable International Preliminary Examination Report in regard to novelty and inventive step with respect to Claims 2-21 and 23-70.

Respectfully submitted,

22 October 2003
Date: (22 October 2003)

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Evidence Appdx 5

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference MORGAL 11	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/US02/32550	International filing date *(day/month/year)* 11 October 2002 (11.10.2002)	Priority date *(day/month/year)* 11 October 2001 (11.10.2001)
International Patent Classification (IPC) or national classification and IPC IPC(7): H01L 31/052; F24J 2/08; G02B 3/00, 3/08 and US Cl.: 136/246; 126/698; 359/733, 741, 742		
Applicant MORGAL, RICHARD		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 3 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of — sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of report with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand 08 May 2003 (08.05.2003)	Date of completion of this report 13 November 2003 (13.11.2003)
Name and mailing address of the IPEA/US Mail Stop PCT, Attn: IPEA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (703)305-3230	Authorized officer Alan Diamond Telephone No. 703-308-0661

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/US02/32550

I. Basis of the report

1. With regard to the **elements** of the international application:*

☒ the international application as originally filed.

☒ the description:
pages 1-21 as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of ______.

☒ the claims:
pages 22-28, as originally filed
pages NONE, as amended (together with any statement) under Article 19
pages NONE, filed with the demand
pages NONE, filed with the letter of ______.

☒ the drawings:
pages 1-16, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of ______.

☐ the sequence listing part of the description:
pages NONE, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of ______.

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language _____ which is:

☐ the language of a translation furnished for the purposes of international search (under Rule23.1(b)).

☐ the language of publication of the international application (under Rule 48.3(b)).

☐ the language of the translation furnished for the purposes of international preliminary examination(under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

☐ contained in the international application in printed form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☐ The amendments have resulted in the cancellation of:

☐ the description, pages NONE

☐ the claims, Nos. NONE

☐ the drawings, sheets/~~fig~~ NONE

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

** Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*
*** Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.*

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/US02/32550

V. Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. STATEMENT

Novelty (N)	Claims 2-21, 23-40	YES
	Claims 1, 22, 41-70	NO
Inventive Step (IS)	Claims 2-21, 23-40	YES
	Claims 1, 22, 41-70	NO
Industrial Applicability (IA)	Claims 1-70	YES
	Claims NONE	NO

2. CITATIONS AND EXPLANATIONS

Claims 1 and 22 lack novelty under PCT Article 33(2) as being anticipated by Cluff, U.S. Patent 4,771,764. Cluff teaches a water-borne azimuth-altitude tracking solar concentrator and converting system employing multiple lens collectors for redirecting sunlight for concentration on photovoltaic cells (see Figure 1; and col. 1, line 50 through col. 2, line 28). A floating platform (32) tracks the sun and is moved azimuthally each day (see col. 3, lines 34-51). In particular, the platform is rotated, and solar panels (40) can be elevated, as seen in Figure 7 (see also col. 3, lines 52-60; and col. 6, lines 11-29). Since Cluff teaches the limitations of the instant claims, the reference is deemed to be anticipatory.

Claims 41-70 lack novelty under PCT Article 33(2) as being anticipated by Touchais et al, U.S. Patent 4,496,787. As seen in Figure 1, each subregion of Touchais et al's lens is configured to distribute light substantially uniformly toward the target. It should be noted that in Touchais et al, the "energy collection target" is the focal point (f) upon which the beams of light converge. It is the Examiner's position that the "focal point" has a finite area, and that the light is distributed "substantially uniformly" toward the focal point. Since Touchais et al teaches the limitations of the instant claims, the reference is deemed to be anticipatory.

Claims 41-70 lack novelty under PCT Article 33(2) as being anticipated by McGrew, U.S. Patent 4,204,881. As seen in Figure 1, each subregion of McGrew's lens is configured to distribute light toward the target. It is the Examiner's position that the light distribution of McGrew's lens inherently is "substantially uniformly toward the target". It should be noted that "substantially uniform" does not require absolute uniformity. McGrew's lens at least provides a distribution that is close to being uniform or is uniform. Since McGrew teaches the limitations of the instant claims, the reference is deemed to be anticipatory.

Claims 41-70 lack novelty under PCT Article 33(2) as being anticipated by O'Neill, U.S. Patent 4,069,812. As seen in Figures 6-11, each subregion of O'Neill's lens is configured to distribute light substantially uniformly toward the target. It should be noted that "substantially uniform" does not require absolute uniformity. O'Neill's lens at least provides a distribution that is close to being uniform or is uniform. Since O'Neill teaches the limitations of the instant claims, the reference is deemed to be anticipatory.

Claims 2-21 and 23-40 meet the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest the particular apparatus features that are set forth in these claims.

Claims 1-70 meet the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.

Evidence Appdx 6

United States Patent [19]

Cluff

[11] **Patent Number:** **4,771,764**

[45] **Date of Patent:** **Sep. 20, 1988**

[54] **WATER-BORNE AZIMUTH-ALTITUDE TRACKING SOLAR CONCENTRATORS**

[76] Inventor: **C. Brent Cluff,** 310 W. Camino Fairhaven, Tucson, Ariz. 85704

[21] Appl. No.: **597,643**

[22] Filed: **Apr. 6, 1984**

[51] **Int. Cl.⁴** **F24J 3/00**

[52] **U.S. Cl.** **126/440;** 126/425; 126/438

[58] **Field of Search** 126/440, 424, 425, 438, 126/439

[56] **References Cited**

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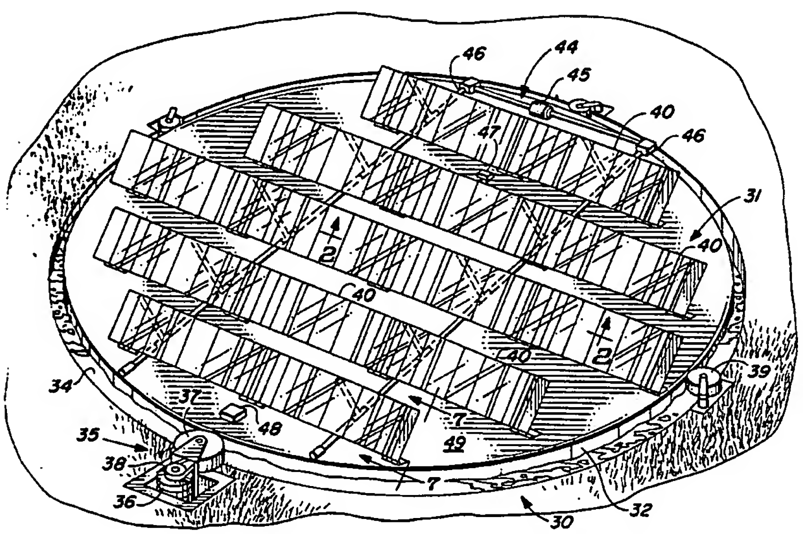
Primary Examiner—Larry Jones

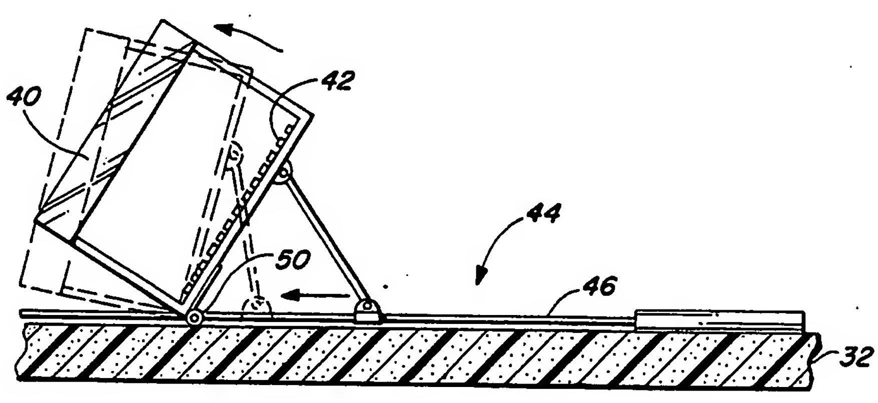
Attorney, Agent, or Firm—Warren F. B. Lindsley

[57] **ABSTRACT**

A water-borne tracking solar energy collecting and converting system employing multiple lens collectors for redirecting sunlight for concentration on photovoltaic cells.

1 Claim, 6 Drawing Sheets





Evidence Appdx 7

US005445177A

United States Patent [19]

Laing et al.

[11] **Patent Number: 5,445,177**

[45] **Date of Patent: Aug. 29, 1995**

[54] **PLATFORM FOR THE UTILIZATION OF SOLAR POWER**

[76] Inventors: **Johanes L. N. Laing; Inge Laing,** both of 1253 La Jolla Rancho Rd., La Jolla, Calif. 92037

[21] Appl. No.: **781,250**

[22] PCT Filed: **Apr. 26, 1991**

[86] PCT No.: **PCT/EP91/00808**

§ 371 Date: **Mar. 5, 1992**

§ 102(e) Date: **Mar. 5, 1992**

[87] PCT Pub. No.: **WO91/17573**

PCT Pub. Date: **Nov. 14, 1991**

[30] **Foreign Application Priority Data**

Apr. 30, 1990 [DE] Germany 40 13 843.7

[51] **Int. Cl.**^{6} **H01L 31/052; F24J 2/00**

[52] **U.S. Cl.** **136/246;** 136/248; 126/565; 126/567; 126/568; 126/698

[58] **Field of Search** 136/246, 248; 126/565-568, 698-700, 705-708

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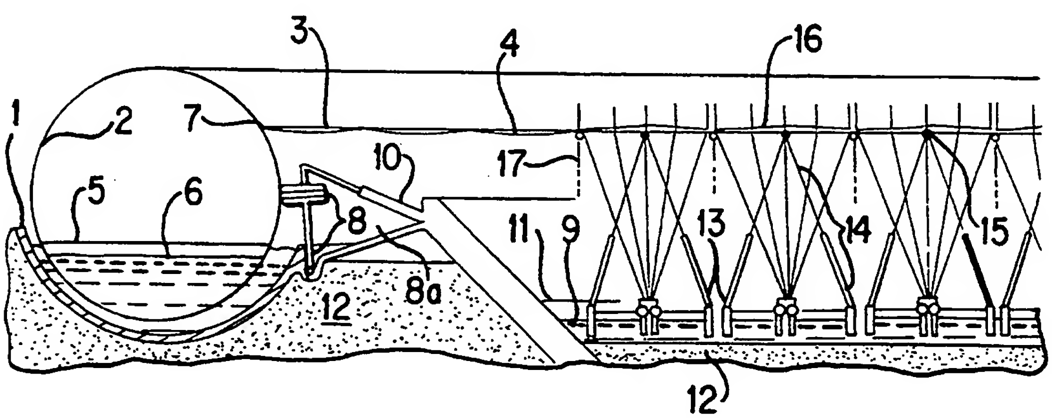
Primary Examiner—Aaron Weisstuch

[57] **ABSTRACT**

The invention relates to a platform of the utilization of solar power which makes use of linear concentrators to beam the solar radiation for use in thermal, chemical or photovoltaic solar power converters, in which the azimuthal movement of the sun is followed by rotation about the main axis. The aim of the invention is to ensure an approximately uniform conversion rate of the solar radiation largely independently of the height of the sun while avoiding the use of a twin-axis follower system. The area available for utilizing the solar power is to be used as fully as possible as the aperture area to capture the radiation. According to the invention, a floating pipe (2, 2', 112) forming a torus is fitted as a frame for a horizontally extending planar bearer (3-4) held, by substantially evenly distributed buoyant bodies (13, 36, 46, 64*a*, 64*b*, 80*b*) borne by a liquid, at a vertical distance from solar power converting devices (33, 53, 73, 73', 93, 94*b*).

24 Claims, 11 Drawing Sheets



Evidence Appdx 8

United States Patent [19]

Genequand et al.

[11] **4,238,246**

[45] **Dec. 9, 1980**

[54] **SOLAR ENERGY SYSTEM WITH COMPOSITE CONCENTRATING LENSES**

[75] Inventors: **Pierre Genequand**, Geneva, Switzerland; **Virgil Stark**, New York, N.Y.

[73] Assignee: **North American Utility Construction Corp.**, New York, N.Y.

[21] Appl. No.: **44,902**

[22] Filed: **Jun. 4, 1979**

[51] **Int. Cl.**^{3} **H01L 3/04; F24J 3/02**

[52] **U.S. Cl.** **136/248**; 126/438; 126/439; 126/440; 136/246; 350/202; 350/211

[58] **Field of Search** .... 136/89 PC, 89 HY, 89 CA; 126/438, 439, 440; 350/211, 202

[56] **References Cited**

U.S. PATENT DOCUMENTS

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4,022,186	5/1977	Northrup, Jr.	126/440
4,069,812	1/1978	O'Neill	136/89 PC
4,134,393	1/1979	Stark et al.	136/89 HY X

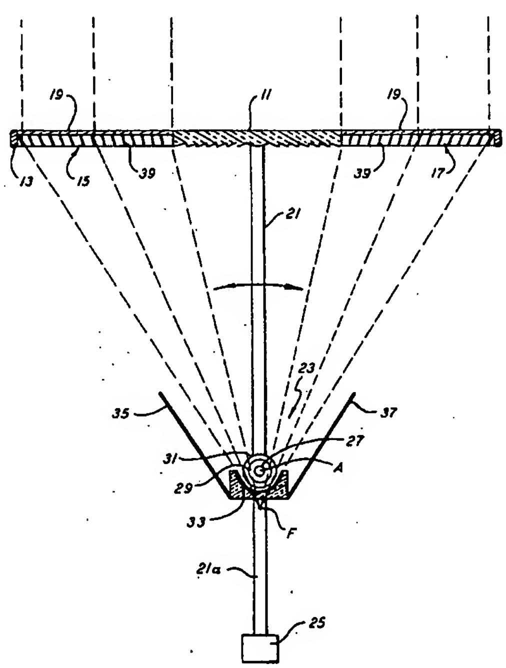
Primary Examiner—Aaron Weisstuch

Attorney, Agent, or Firm—Kenyon & Kenyon

[57] **ABSTRACT**

In order to improve the efficiency of a solar energy system utilizing a Fresnel lens for concentrating solar rays on a conduit system or the like, only the central portion of a Fresnel lens, otherwise of large width, is utilized and slide assemblies, each containing a plurality of slats with a reflective coating and disposed at an angle such as to reflect solar energy to the same focal point as the Fresnel lens, are disposed on each side of the lens thereby effectively increasing the aperture of the lens and increasing efficiency of concentration.

10 Claims, 1 Drawing Figure



throttle valve. 2. See **throttle valve.** 3. the throat, gullet, or windpipe, as of a horse. [prob. dim. of ME *throte* THROAT; cf. G *Drossel*]
—*v.t.* 4. to stop the breath of by compressing the throat; strangle. 5. to choke or suffocate in any way. 6. to compress by fastening something tightly around. 7. to silence or check as if by choking: *His message was throttled by censorship.* 8. *Mach.* **a.** to obstruct or check the flow of (a fluid), as to control the speed of an engine. **b.** to reduce the pressure of (a fluid) by passing it from a smaller area to a larger one. [late ME *throtel*, freq. of *throte(n)* (to) cut the throat of (someone), strangle, deriv. of THROAT] —**throt′tler,** *n.*

Throt·tle·bot·tom (throt′ᵊl bot′əm), *n.* (*sometimes l.c.*) a harmless incompetent in public office. [named after Alexander *Throttlebottom*, character in *Of Thee I Sing* (1932), musical comedy by George S. Kaufman and Morris Ryskind]

throt′tle lev′er, throttle (def. 1).

throt′tle valve′, a valve for throttling the working fluid of an engine, refrigerator, etc.

through (thro͞o), *prep.* 1. in at one end, side, or surface and out at the other: *to pass through a tunnel; We drove through Denver without stopping. Sun came through the window.* 2. past: *to go through a stop sign without stopping.* 3. from one to the other of; between or among the individual members or parts of: *to swing through the trees; This book has passed through many hands.* 4. over the surface of, by way of, or within the limits or medium of: *to travel through a country; He flies through the air with the greatest of ease.* 5. during the whole period of; throughout: *He worked through the night.* 6. having reached the end of: *to be through one's work.* 7. to and including: *from 1900 through 1950.* 8. having finished successfully: *to get through an examination.* 9. by the means or instrumentality of; by the way or agency of: *It was through him they found out.* 10. by reason of or in consequence of: *to run away through fear.* 11. in at the first step of a process, treatment, or method of handling, passing through subsequent steps or stages in order, and finished, accepted, or out of the last step or stage: *The body of a car passes through 147 stages on the production line. The new tax bill finally got through Congress.* —*adv.* 12. in at one end, side, or surface and out at the other: *to push a needle through; We don't live here, we're just passing through.* 13. all the way; along the whole distance: *This train goes through to Boston.* 14. throughout: *soaking wet through.* 15. from the beginning to the end: *to read a letter through.* 16. to the end: *to carry a matter through.* 17. to a favorable or successful conclusion: *He barely managed to pull through.* 18. having completed an action, process, relationship, etc.: *Please be still until I'm through.* 19. **through and through, a.** through the whole extent of; thoroughly: *wet and cold through and through.* **b.** from beginning to end; in all respects: *an aristocrat through and through.* 20. **through with, a.** finished with. **b.** at the end of all relations or dealings with: *My sister again insists that she's through with men.* —*adj.* 21. passing or extending from one end, side, or surface to the other. 22. traveling, conveying, or extending through the whole of a long distance with little or no interruption: *a through train.* 23. (of a road, route, way, course, etc. or of a ticket, routing order, etc.) admitting continuous or direct passage; having no interruption, obstruction, or hindrance: *a through highway; through ticket.* 24. (of a bridge truss) having a deck or decks within the depth of the structure. Cf. **deck** (def. 12). [ME, metathetic var. of *thourgh*, OE *thurh*; c. G *durch*; akin to OE *therh*, Goth *thairh* through, OHG *derh* perforated, OE *thyrel* full of holes (adj.), hole (n.). See THIRL, NOSTRIL]
—**Syn. 9.** See **by.**

through′ bass′ (bās). See **thorough bass.**

through-com·posed (thro͞o′kəm pōzd′), *adj.* having different music for each verse: *a through-composed song.* Cf. **strophic** (def. 2).

through·ly (thro͞o′lē), *adv.* *Archaic.* thoroughly. [late ME; see THROUGH, -LY]

through-oth·er (thro͞o′uth′ər), *adj.* *Chiefly Scot.* confused. Also, **through-ith·er** (thro͞o′ith′ər).

through·out (thro͞o out′), *prep.* 1. in or to every part of; everywhere in: *They searched throughout the house.* 2. from the beginning to the end of: *He was bored throughout the play.* —*adv.* 3. in every part: *rotten throughout.* 4. at every moment or point: *Follow my plan throughout.* 5. from the beginning to the end: *to read a book throughout.* [ME *throw out*, OE *thurh ūt*. See THROUGH, OUT]

through·put (thro͞o′po͝ot′), *n.* the quantity or amount of raw material processed within a given time, esp. the work done by an electronic computer in a given period of time. Also, **thruput.** [n. use of v. phrase *put through*, modeled on *output*]

through′ stone′, perpend¹.

through′ street′, a street on which the traffic has the right of way over vehicles entering or crossing at intersections. Cf. **stop street.**

Through′ the Look′ing-Glass, a story for children (1871) by Lewis Carroll: the sequel to *Alice's Adventures in Wonderland.*

through·way (thro͞o′wā′), *n.* thruway.

throve (thrōv), *v.* a pt. of **thrive.**

throw (thrō), *v.,* **threw, thrown, throw·ing,** *n.* —*v.t.* 1. to propel or cast in any way, esp. to project or propel from the hand by a sudden forward motion or straightening of the arm and wrist: *to throw a ball.* 2. to hurl or project (a missile), as a gun does. 3. to project or cast (light, a shadow, etc.). 4. to project (the voice): *He threw his voice so that all might hear.* 5. to make it appear that one's voice is coming from a place different from its source, as in ventriloquism: *When he threw his voice we all thought someone had been locked in the trunk.* 6. to direct or send forth (words, a glance, etc.). 7. to put or cause to go or come into some place, position, condition, etc., as if by hurling: *to throw a man into prison; to throw a bridge across a river; to throw troops into action.* 8. to put on, off, or away hastily: *to throw a shawl over one's shoulders.* 9. *Mach.* **a.** to move (a lever or the like) in order to connect or disconnect parts of an apparatus or mechanism: *to throw the switch.* **b.** to connect, engage, disconnect, or disengage by such a procedure: *to throw the current.* 10. to shape on a potter's wheel: *He threw the clay into a vase.* 11. to exert or bring to bear (influence, resources, or power or authority of any kind): *Throw all your energy into your work. The FBI threw every available agent into the case.* 12. to deliver a blow or punch: *He threw a hard left jab to his opponent's chin.* 13. *Cards.* to play (a card). 14. to cause to fall to the ground, esp. to hurl to the ground, as an opponent in wrestling. 15. *Informal.* to lose (a game, race, or other contest) intentionally, as for a bribe. 16. to cast (dice). 17. to make (a cast) at dice. 18. (of an animal, as a horse) to cause (someone) to fall off; unseat: *The horse threw his rider twice.* 19. (of domestic animals) to bring forth (young). 20. *Textiles.* to twist (filaments) without attenuation in the production of yarn or thread. 21. *Informal.* to overcome with astonishment or confusion; astonish; confuse: *It was her falsetto voice on top of it all that really threw me.* 22. *Obs.* to turn on a lathe. —*v.i.* 23. to cast, fling, or hurl a missile or the like. 24. **throw away, a.** to dispose of; discard. **b.** to employ wastefully; squander. **c.** to fail to use; miss (a chance, opportunity, etc.): *He threw away a college education and a professional career.* 25. **throw back, a.** to retard the development or advancement of: *His illness threw him back a year at school.* **b.** to force into a state of dependence. **c.** to return to; hark back. **d.** to revert to a type found in one's ancestry; manifest atavism: *Her red hair and blue eyes throw back to her great-grandmother.* 26. **throw cold water on.** See **cold** (def. 18). 27. **throw down the gauntlet or glove.** See **gauntlet**¹ (def. 4). 28. **throw in, a.** *Informal.* a. to add as a bonus or gratuity: *They throw in breakfast with the room.* **b.** to bring into (a discussion, plan, etc.) as an addition; interpolate: *The chairman threw in an amusing anecdote to relieve the tension.* **c.** *Cards.* to abandon (a hand). 29. **throw in the sponge.** See **sponge** (def. 12). 30. **throw in the towel.** See **towel** (def. 2). 31. **throw off, a.** to free oneself of; cast aside: *to throw off the yoke of slavery.* **b.** to escape from or delay, as a pursuer. **c.** to give off; discharge. **d.** to perform or produce with ease: *The entertainer threw off a few songs and jokes to begin the show.* **e.** to confuse; fluster: *Thrown off by jeers, she forgot her lines.* 32. **throw oneself at (someone) or at (someone's head),** (of a woman) to strive to attract the interest or attention of, esp. in order to win the love or admiration of: *She throws herself at any man who will look at her.* 33. **throw oneself into,** to engage in with energy or enthusiasm: *She threw herself into making costumes for her daughter's dance recital.* 34. **throw oneself on** or **upon (someone),** to commit oneself to another's mercy, generosity, support, etc.; trust in: *The members of his wife's family have all thrown themselves on him.* 35. **throw out, a.** to cast away; remove; discard. **b.** to bring up for consideration; propose: *The committee threw out a few suggestions.* **c.** to put out of mind; reject: *We can throw out that scheme.* **d.** *Baseball.* to cause to be out by throwing the ball to a fielder, esp. an infielder, in time to prevent a batter or runner from reaching base safely: *The shortstop backhanded the ball and threw the batter out at first.* **e.** to eject from a place; remove, esp. forcibly: *He started making a disturbance so the bartenders threw him out.* 36. **throw over,** to forsake; abandon: *She threw over her first husband for a richer man.* 37. **throw the bull.** See **bull**³ (def. 2). 38. **throw together, a.** to make in a hurried and haphazard manner. **b.** to cause to associate: *Many races and nationalities have been thrown together in the American melting pot.* 39. **throw up, a.** to give up; relinquish. **b.** to build hastily. **c.** to vomit. **d.** to point out, as an error; criticize. **e.** (of a hawk) to fly suddenly upward.
—*n.* 40. the act or an instance of throwing or casting; cast; fling. 41. the distance to which anything is or may be thrown: *a stone's throw.* 42. *Informal.* a venture or chance: *It was his last throw.* 43. *Mach.* **a.** the distance between the center of a crankshaft and the center of the crankpins, equal to one half of the piston stroke. **b.** the distance between the center of a crankshaft and the center of an eccentric. **c.** the movement of a reciprocating part in one direction. 44. (in a motion-picture theater) the distance between the projector and the screen. 45. (in an auditorium or the like) the distance between a loudspeaker and the audience. 46. length of a beam of light: *a spotlight with a throw of 500 feet.* 47. a scarf, boa, or the like. 48. *Theat.* **a.** the distance to which a spotlight can be projected. **b.** the area illuminated by a spotlight. 49. a light blanket, as for use when reclining on a sofa; afghan. 50. a cast of dice. 51. the number thrown with a pair of dice. 52. *Wrestling.* the act, method, or an instance of throwing an opponent. 53. *Geol., Mining.* the amount of vertical displacement produced by a fault. [ME *throw(en)*, *thrawen*, OE *thrāwan* to twist, turn; c. D *draaien*, G *drehen* to turn, spin, twirl, whirl; akin to L *terere*, Gk *teírein* to rub away]
—**Syn. 1.** fling, launch, send. THROW, CAST, PITCH, TOSS imply projecting something through the air. THROW is the general word, often used with an adverb which indicates direction, destination, etc.: *to throw a rope to him, the paper away.* CAST is a formal word for THROW, archaic except as used in certain idiomatic expressions (*to cast a net, black looks; cast down;* the compound *broadcast*, etc.): *to cast off a boat.* PITCH implies throwing with some force and definite aim: *to pitch a baseball.* To TOSS is to throw lightly, as with an underhand or sidewise motion, or to move irregularly up and down or back and forth: *to toss a bone to a dog.*

throw·a·way (thrō′ə wā′), *n.* any advertisement, as a folder or a broadside, passed out on streets, slipped under doors, etc. [n. use of v. phrase *throw away*]

throw·back (thrō′bak′), *n.* 1. an act of throwing back. 2. a setback or check. 3. the reversion to an ancestral or earlier type or character; atavism. 4. an example of this. [n. use of v. phrase *throw back*]

throw·er (thrō′ər), *n.* 1. one who or that which throws. 2. flinger (def. 2). [late ME; see THROW, -ER¹]

throw′ing stick′, 1. a slinglike device used in various primitive societies for propelling a weapon, as a spear, javelin, or the like. 2. *Australian.* boomerang.

thrown (thrōn), *v.* a pp. of **throw.**

thrown′ silk′, raw silk that has been reeled and twisted into yarn. Also called, *Brit.*, **net silk.**

throw′ rug′. See **scatter rug.**

throw·ster (thrō′stər), *n.* one who throws silk or man-made filaments. [late ME *throwestre.* See THROW, -STER]

thru (thro͞o), *prep., adv., adj.* *Informal.* through.

thrum¹ (thrum), *v.,* **thrummed, thrum·ming,** *n.* —*v.i.* 1. to play on a stringed instrument, as a guitar, by plucking the strings, esp. in an idle, monotonous, or unskillful manner. 2. to sound when thrummed on, as a guitar or similar stringed instrument. 3. to drum or tap idly with the fingers. —*v.t.* 4. to play (a stringed instrument, or a melody on it) by plucking the strings, esp. in an idle, monotonous, or unskillful manner. 5. to drum or tap idly on. 6. to recite or tell in a monotonous way. —*n.* 7. the act or sound of thrumming; dull, monotonous sound. [imit.] —**thrum′mer,** *n.*

thrum² (thrum), *n., v.,* **thrummed, thrum·ming.** —*n.* 1. one of the ends of the warp threads in a loom, left unwoven and remaining attached to the loom when the web is cut off. 2. **thrums,** the row or fringe of such threads. 3. any short piece of waste thread or yarn; tuft, tassel, or fringe of threads, as at the edge of a piece of cloth. 4. Often, **thrums.** *Naut.* short bits of rope yarn used for making mats. —*v.t.* 5. *Naut.* to insert short pieces of rope yarn through (canvas) and thus give it a rough surface, as for wrapping about a part to prevent chafing. 6. *Archaic.* to furnish or cover with thrums, ends of thread, or tufts. [ME *throm* end-piece, OE *-thrum* ligament; c. OHG *drum* end-piece; akin to Icel *thröm(r)* brim, edge, L *terminus*, Gk *térma* end]

thrum·my (thrum′ē), *adj.,* **-mi·er, -mi·est.** of or abounding in thrums; shaggy or tufted. [THRUM² + -Y¹]

thrump (thrump), *n.* a thumping, rumbling sound, usually repetitive: *the thrump of artillery echoing through the valley.* [imit.]

Wood thrush, *Hylocichla mustelina* (Length 8 in.)

thrup·pence (thrup′əns), *n.* threepence.

thru·put (thro͞o′po͝ot′), *n.* throughput.

thrush¹ (thrush), *n.* 1. any of numerous, cosmopolitan, passerine birds of the family *Turdidae*, many species of which are noted as songbirds. 2. any of various unrelated, superficially similar birds, as the water thrushes. 3. *Slang.* a female professional singer, esp. of popular songs. [ME *thrusche*, OE *thrysce;* c. OHG *drōsca*] —**thrush′like′,** *adj.*

thrush² (thrush), *n.* 1. *Pathol.* a disease, esp. in children, characterized by whitish spots and ulcers on the membranes of the mouth, fauces, etc., caused by a parasitic fungus, *Candida albicans.* 2. (in horses) a diseased condition of the frog of the foot. [akin to Dan *tröske*, Sw *torsk*]

thrust (thrust), *v.,* **thrust, thrust·ing,** *n.* —*v.t.* 1. to push forcibly; shove; put or drive with force: *He thrust his way through the crowd. She thrust a dagger into his back.* 2. to impose acceptance of; put boldly into some position, condition, etc.: *to thrust oneself into a conversation between others; to thrust a dollar into the waiter's hand.* 3. to stab or pierce, as with a sword: *She thrust his back with a dagger.* 4. to extend; present: *He thrust his fist in front of my face.* —*v.i.* 5. to push against something. 6. to push or force one's way, as against obstacles or through a crowd. 7. to make a thrust, lunge, or stab at something. —*n.* 8. the act or an instance of thrusting; a forcible push or drive; lunge or stab. 9. *Mach.* a linear reactive force exerted by a propeller, propulsive gases, etc., to propel a vessel, aircraft, etc. 10. *Geol.* a compressive strain in the crust of the earth, which, in its most characteristic development, produces reversed or thrust faults. 11. *Mech.* a pushing force or pressure exerted by a thing or a part against a contiguous one. 12. *Archit.* the downward and outward force exerted by an arch on each side. 13. an organized military attack; assault; offensive. [ME *thrust(en)*, *thrysten* < Scand; cf. Icel *thrysta* to thrust]
—**Syn. 6.** shove.

thrust′ augmenta′tion, *Rocketry.* an increase in the thrust of a jet or rocket engine, as by afterburning or reheating.

thrust′ bear′ing, *Mach.* a bearing designed to absorb thrusts parallel to the axis of revolution.

thrust′ coeffi′cient, *Rocketry.* the ratio of the thrust of a rocket engine, operating under given conditions, to the product of the mean pressure in the combustion chamber and the cross-sectional area of the throat of the nozzle.

thrust′ deduc′tion, *Naut.* a decrease in the effective thrust of a propeller caused by the movement aft of water past the run of the hull.

thrust·er (thrus′tər), *n.* 1. one who or that which thrusts. 2. *Fox Hunting.* a bold rider who keeps in the front of the field, following hounds in the most direct way. [THRUST + -ER¹]

thrust′ fault′, *Geol.* a fault along an inclined plane in which the side or hanging wall appears to have moved upward with respect to the lower side or footwall (contrasted with *gravity fault*).

thru·way (thro͞o′wā′), *n.* a limited-access toll highway providing a means of direct transportation between distant areas for high-speed automobile traffic. Also, **throughway.** [THRU + WAY]

Thrym (thrym), *n.* *Scand. Myth.* a giant who, having demanded Freya in return for the stolen hammer of Thor, was killed by Thor, who came disguised as Freya.

thrym·sa (thrim′zə, -sə), *n.* an Anglo-Saxon gold coin of the 7th century. [OE (gen. pl.), alter. of *trymsa* (by influence of *thrie* three), gen. pl. of *trymes* < LL *tremis* a coin < L *trē(s)* three + *-mis*, as in *semis*]

Thu·cyd·i·des (tho͞o sid′i dēz′), *n.* c460–c400 B.C., Greek historian.

thud (thud), *n., v.,* **thud·ded, thud·ding.** —*n.* 1. a dull sound, as of a heavy blow or fall. 2. a blow causing such a sound. —*v.i., v.t.* 3. to beat or strike with a dull sound of heavy impact. [ME *thudd(en)*, OE *thyddan* to strike, press] —**thud′ding·ly,** *adv.*